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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

A REPORT ON THE

PROPERTIES AND WELDING CHARACTERISTICS OF

STRUCTURAL T-1 STEEL

56-13

MATERIALS AND RESEARCH DEPARTMENT

State of California
Department of Public Works
Division of Highways
Materials and Research Department

April 2, 1956

Laboratory Project
Authorization No. 6046

F. W. Panhorst
Assistant State Highway Engineer
Bridge Department
Public Works Building
Sacramento, California

Dear Sir:

Submitted for your consideration is:

A REPORT OF

THE PROPERTIES AND WELDING CHARACTERISTICS

OF STRUCTURAL T-1 STEEL

Study made by . . . . Structural Materials Section
Under general direction of . . . . J. L. Beaton
Work supervised by . . . . P. G. Jonas
Report prepared by . . . . P. G. Jonas and C. B. Kendrick

Very truly yours,

F. N. Hveem

F. N. Hveem
Materials and Research Engineer

cc: ALElliott
IOJahlstrom
LCHollister
EWithycombe

April 2, 1956

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limits specified by the electrode manufacturers. The manual welding was executed by State certified journeyman welders in the presence and under the direction of a laboratory representative. The plates were welded in a flat position (see Exhibit 29). After each pass slag was cleaned from the welds with a welder's slagging hammer and a wire brush.

The welding was started with the plates at room temperature (without preheat). The time between welding passes was controlled, using both a pyrometer and temperature crayons, such that the temperature of the plate 1 inch from the weld did not exceed 400°F. Each plate was cooled normally (by air convection) to room temperature after the weld was finished.

The power for the manual welding was provided by a General Electric 300 ampere direct current welding machine. The welding amperage settings and polarity recommended by the electrode manufacturer were followed closely. These settings were dependent on the type and size of electrode, the type and size of groove, the fitup, the plate thickness, and the weld pass number.

The welds were radiographically inspected, using gamma ray techniques, for defects equal or exceeding 2% of the plate thickness in dimension. This inspection revealed inclusions in the A. O. Smith weld on the 1" plate, and the Unionmelt weld on the ½" plate. The former was trimmed such that defective portions of the weld were discarded, and the latter was rewelded. Radiographic inspection revealed no further internal defects in all of the welds tested.

The welding of the test plates proceeded smoothly with no spatter, and it was completed without incident. These welds represent the type that may be expected from fabricating shops operating under normal rather than ideal conditions and using the welding processes, procedures, and electrodes listed in this report.

FATIGUE SPECIMEN

The fatigue machine was designed to utilize a specimen (see Exhibits 121 through 124) of relatively large cross-sectional area 3/4" diameter through the maximum stress point, which was located at the base of the fillet. This large cross-section was necessary in order to incorporate as much weld material into the high stress area as could be effected. The specimen as shown was designed with extended non-tapered tail and grip sections in order to lower machining costs and to facilitate easier use in the fatigue machine. The welded fatigue specimens were prepared from the welded plate, keeping the welds at the fillet root as shown in Exhibits 123 and 124. The fillet radius was made as large as possible in order to reduce the fillet notch effect. The resulting notch coefficient of 1.05 for this fillet radius was not considered of sufficient magnitude to detract from establishing the nominal stresses on account of an undetermined notch effect introduced by the weld itself. Fatigue tests were not performed on the ½" welded T-1 plate.

FATIGUE MACHINE

A single-end rotating cantilever fatigue machine was used to perform all fatigue testing. This machine (see Exhibits 120 and 122) was driven at 6000 rpm through a Cleveland Variable Speed gearbox by a $1\frac{1}{2}$ hp motor. The nominal fiber stresses, which the machine imposed on a specimen at the fillet root, were calibrated statically with a load cell and plotted against the weights and lever arms used (see Exhibit 121). The weight of the specimen and tail collet, and the changes in leverage caused by the deflection of the tail or cantilevered end of the specimen were considered in the load calibration of the machine. Attempts at dynamic calibration using SR4 strain gauges were unsatisfactory and are not tabulated. Cycles (total revolutions) were counted with a Berkeley Electronic Counter and checked against the product of the test period in minutes multiplied by the revolutions per minute.

As reported below, static and dynamic deflections at the cantilevered end of the specimens were measured electronically with a differential transformer. The dynamic temperatures of the critical or maximum stress section were measured with a thermocouple through a slip ring.

A series of fatigue tests were run with ASTM A-7 steel in order to acquire operating experience; to observe the performance of the machine; and, based on these observations, to make any necessary modifications in procedures. The data thus acquired was used as a basis for the qualitative comparison of this machine with other fatigue machines in order to ascertain in a general way its effectiveness as a fatigue testing device. The value of 30,800 psi obtained for the endurance limit of A-7 steel (not using the notch factor of 1.05) compared favorably with the 32,000 psi endurance limit listed for hot rolled 0.20% carbon steel in the ASM Metals Handbook, page 119, Table I.

Eight of the welded and parent metal specimens which were stressed above 50,000 psi and which ran longer than 2 x 10^6 cycles, failed through the gripped section. This breakage appears to have been aggravated by fretting corrosion plus a possible third harmonic vibration. The computed resonance of the section through the grip was near 2000 cycles per minute, whereas the speed employed was 6000 rpm. However, the data from these specimens was in line with the balance of the specimens and therefore it is considered that the results were not adversely affected.

FATIGUE TEST PROCEDURE

Five fatigue tests were made on each welded plate. A nominal stress of 50% to 60% of the ultimate strength of the weld was applied in the initial test from each plate, and the load was reduced on successive test specimens until the final specimen endured 10^7 cycles without failure.

These final specimens were retested (Footnote 1) at a higher stress (damage checked) in order to observe how the cyclic stress history of the specimens affected their fatigue strength. This information was used to check the critical points on the S-N curve.

TREATMENT OF FATIGUE DATA

The static and dynamic deflections of the cantilevered end of the specimen were not considered reliable in establishing the stresses in the specimen on account of (1) the undefinable notch effect of the weld and (2) the uncertain interpretation of the dynamic reading. The dynamic temperatures recorded (which were often 70° or more above room temperature) were not sufficiently precise to be informative, as the recording method was not free enough from heat loss and other variables to be effectively analyzed without further test information. Therefore, the deflection and temperature data is not included in this report.

The S-N diagram (stress versus cycles to failure) for the T-1 steel and for each weld tested was plotted on a log-log system of coordinates. (See Appendix Section F). The best line through and the negative probable error for each set of data was calculated from least square formulas and entered on a graph with the appropriate data. Since a large number of the tests could not be made, the data of the weld fatigue tests were not separated according to plate thickness. The scatter was such that it was necessary to combine all the fatigue data from each weld process in order to evaluate this data with logical results.

The ordinates of the horizontal portions of the S-N diagrams corresponding to the endurance limits were estimated from the data by visual inspection. These estimates of the endurance limits are considered as the maximum that can be permitted on the basis of these test results.

OTHER PHYSICAL SPECIMENS

The other physical test specimens,- tensiles, bends, impacts, and hardness surveys,- were prepared and were examined according to standard ASTM and AWS procedures where such were specified. The yield strengths of the butt weld tensile specimens were determined by the "drop of the beam" or the "halt of the dial" method. The 0.2% offset yield strengths of all the parent metal specimens (except the 2" strap tensile from the ½" plate and the .505" diameter tensiles) were taken from the corresponding stress-strain curves. The net ultimate and

- -

Footnote 1. When the fatigue strength of a retested specimen exceeds its probable fatigue strength in the virgin state, it is said to have been "coaxed" to a higher fatigue strength. It is possible to raise the endurance limit of a specimen about 25% by subjecting it to a series of 4×10^6 or more stress reversals starting with an applied stress below the virgin endurance limit and increasing the stress slightly with each series of reversals until a new endurance limit is reached. This practice is called "coaxing".

yield strength reported for each thickness of the parent metal was an average taken from all the parent metal tensile specimens for that thickness. This ultimate strength was used in calculating the joint efficiencies of the various welds used on the corresponding plate. The net percent reduction of areas illustrated in Exhibit 8A for the parent metal plate, were based on the 2" and 8" strap tensile specimens, because the cross-section of these tensiles could be compared with that of the butt weld tensile specimens. Similarly, the percent elongation reported for the parent metal was taken from the 2" strap tensiles in order that these figures might be compared with the butt weld tensile specimens.

The tensile strengths listed on the S-N diagrams were taken from standard .505" diameter weld metal plug tensile specimens. These weld metal samples were prepared by fusing electrodes to fill a form about 1" x 1" x 12" in dimension, made from the T-1 plate, and were then machined into a tensile specimen as noted. Tensile testing was performed with a 200,000 lb. capacity Baldwin Universal Testing machine and a 60,000 lb. capacity Riehle machine.

The V notch Charpy impact tests, which were conducted according to ASTM procedures at 0° Fahrenheit, show a wide divergence of the resulting energies absorbed in fracturing the specimens. However, the averages surpass the 23 foot pound minimum requirement for keyhole Charpy impact energy at 0°F. which is listed in Military Specifications #E-18038 (ships). The keyhole Charpy impact test is considered less severe than the V notch test referred to above. This 23 foot pound minimum is an acceptable value for comparative purposes, and it indicates that unfavorable brittleness was not encountered in (1) the parent metal, (2) the heat affected zone, and (3) the weld metal. This applies to all samples taken from ½", 1", and 1½" butt welded joints (see Exhibit 3).

The hardness survey specimens were prepared by slicing a small sample cross-section from the welds at right angles to the axes of the joints. These cross-sections were smoothed on a belt sander and macro-etched to locate the weld and weld affected areas clearly. A 1/8" grid pattern was drawn on the surface of each cross-section. Rockwell scale hardness measurements in each piece were taken from the intersections in the grid. These measurements are plotted on graphs shown in Exhibits 145 through 164 on Appendix Section G.

A number of parent metal pieces were flame cut and machine cut from the sample T-1 plates. These were subjected to side bending. The untreated samples of flame cut edges failed to pass these bend tests (see Exhibit 14). These failures were attributed to hardened metal, slag, scale, and notches remaining on the edges from the flame cutting and scarfing operations.

[illegible]

V. DISCUSSION

The test results for T-1 steel verify the physical properties specified for that steel by the U. S. Steel Corporation. The yield, ultimate strength, and fatigue properties varied inversely with the thickness of the plate as may be noted from Exhibits 5 through 12, with net yield strengths dropping from 120,100 psi for ½" thick plate to 93,100 psi for 1½" thick plate, net ultimate strengths from 130,200 psi to 103,500 psi and rotating bending endurance limits from 58,600 psi to 51,200 psi. Ductility increased with plate thickness and varied inversely with tensile strength, with elongations on the 2" strap tensiles varying from 27.5% to 43.5%. The tensile failures of the parent metal were of the 50% to 100% ductile type of fractures. All the cold bends went 180° without failure.

The parent metal in a preliminary study exhibited a fibrous structure parallel to the rolling direction in failed sections. Microscopic examination revealed some fine porosity parallel to this rolling direction. These facts indicate the possibility of directional properties, although this has not been examined directly. Further metallographic studies are contemplated.

Flame cut edges were so hard that they were difficult to machine. These flame cut sample edges failed in bend tests. Scale and slag remaining from the flame cutting operations are often trapped in subsequent welding. Therefore, prior to welding, a mechanical treatment was necessary in order to remove hardened material, slag, scale, and notches from the flame cut edges. The possibility of developing or modifying a flame cutting procedure to overcome these disadvantages is suggested.

The Aircomatic process using A632 electrode wire with a manual #21 gun and a gas shield of 98% argon and 2% oxygen, produced welds with the most desirable all around physical properties of any tested. These welds showed very little porosity, and they meet the requirements for soundness in the critical or primary welding better than welds produced by the other processes tested.

The A. O. Smith manual low hydrogen process using SW-91 electrodes (E11016 tentative) produced welds with porosity and visible inclusions apparent in about 10% of the failed cross sections. Even so, the joints welded by this process possessed good tensile and fatigue strength with moderate ductility and notch sensitivity. The Unionmelt submerged arc automatic process using Oxwell 866 electrode wire produced ductile welds of moderate tensile strength and notch sensitivity, with good fatigue strength. Here again the welds contained numerous inclusions with visible porosity in about 10% of the failed sections. The test data for both of these processes indicate that if sound welds are produced by either, they will have excellent physical properties despite the moderate or low average properties recorded in this report which resulted from inclusions in some of the welds tested. However, the apparent difficulty encountered in producing a sound weld consistently by either of these processes limits their desirability in critical welding applications. If these problems can be overcome, the use of a submerged arc process would be satisfactory.

The Airco manual low hydrogen processes using E10016 and E12015 electrodes produced welded joints with moderate to excellent tensile strength and ductility, but with endurance limits barely exceeding that of A-7 structural steel. The results indicate that in structural members not subject to excessive fatigue (i.e., fatigue exceeding the capacities of A-7 steel), the other physical properties of these welds might be employed to advantage. Notice from the test data that butt welded joints made with the E12015 electrodes have no positive strength advantage over those made with E10016 electrodes (see Exhibits 5 through 12). Test results, contrary to usual findings, also indicate that the endurance limits for butt welded joints prepared using the harder E12015 electrodes are not greater than for joints prepared with the softer E10016 and E11016 electrodes. The joints prepared from E10016 electrodes reflect the greater strength of the 1" and ½" plate. This is possibly due to dilution of the weld metal by the plate. The E11016 electrode would appear to be ideal for welding T-1 steel. Therefore, the advantages of ductility realized by using E10016 and E11016 electrodes, more than offset the questionable strength advantage of the harder E12015 electrode.

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VI. CONCLUSIONS

(1) Structural T-1 steel may be satisfactorily welded for structural purposes using both automatic and manual processes providing the welding procedures are carried out properly.

(2) A joint efficiency of 95% for structural T-1 steel welded joints can be obtained if based on the usually specified mechanical properties of T-1 steel for structural use. These are:

Ultimate Strength	105,000 psi
Yield Strength	90,000 psi
Elongation in 2"	% Minimum for .505 tensile specimens
18% for 1/4" to 2" incl.	plate thickness
17% for 2" to 4" incl.	plate thickness
16% for 4" to 6" incl.	plate thickness

(3) Narrow tolerances in operating procedures are necessary for the consistent production of satisfactory welds of T-1 structural steel. This will necessitate rigorous prequalification of all welding operators and procedures and will allow no deviation from established procedure.

(4) The inspection methods and techniques used to control the welding procedures employed during this test program conformed to Calif. Test Method 601. These should be followed during actual fabrication except that the specified AWS standard guided bend test may be modified by the use of a bending jig that will produce 13% rather than 20% elongation in the extreme fibre of the bend specimen.

(5) The more ductile E-10016 and E-11016 electrodes produced butt joints with strengths approximately equal to those provided by butt joints welded using the harder E-12015 electrodes. It is considered that the use of E-100 and E-110 series of low hydrogen electrodes will result in an over-all more satisfactory structural weld than can be made by using the E-120 low hydrogen electrodes.

(6) Wherever possible, automatic flame cutting processes should be used when flame cutting T-1 steel. These operations should be so adjusted and controlled as to provide smooth and even flame cut edges and to minimize the hardening of these edges.

(7) T-1 steel flame cut edges which are to be welded should be mechanically treated to remove hardened metal, oxides, scale, and surface irregularities in order to prevent oxidized metal and slag from being trapped in the weld metal during welding operations.

(8) When flame cut edges are exposed, as in the flanges of fabricated members, care should be exercised to keep such edges smooth and even, and free from uneven hardnesses resulting from the flame cutting. It will be necessary that excessively hardened metal, sharp corners, and abrupt surface irregularities be removed from such edges.

[illegible]

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VIII APPENDIX

SECTION A

- -

SUMMARY OF TESTS
AND
TEST RESULTS

PLANS FOR CUTTING

SPECIMEN FROM PLATE

AND

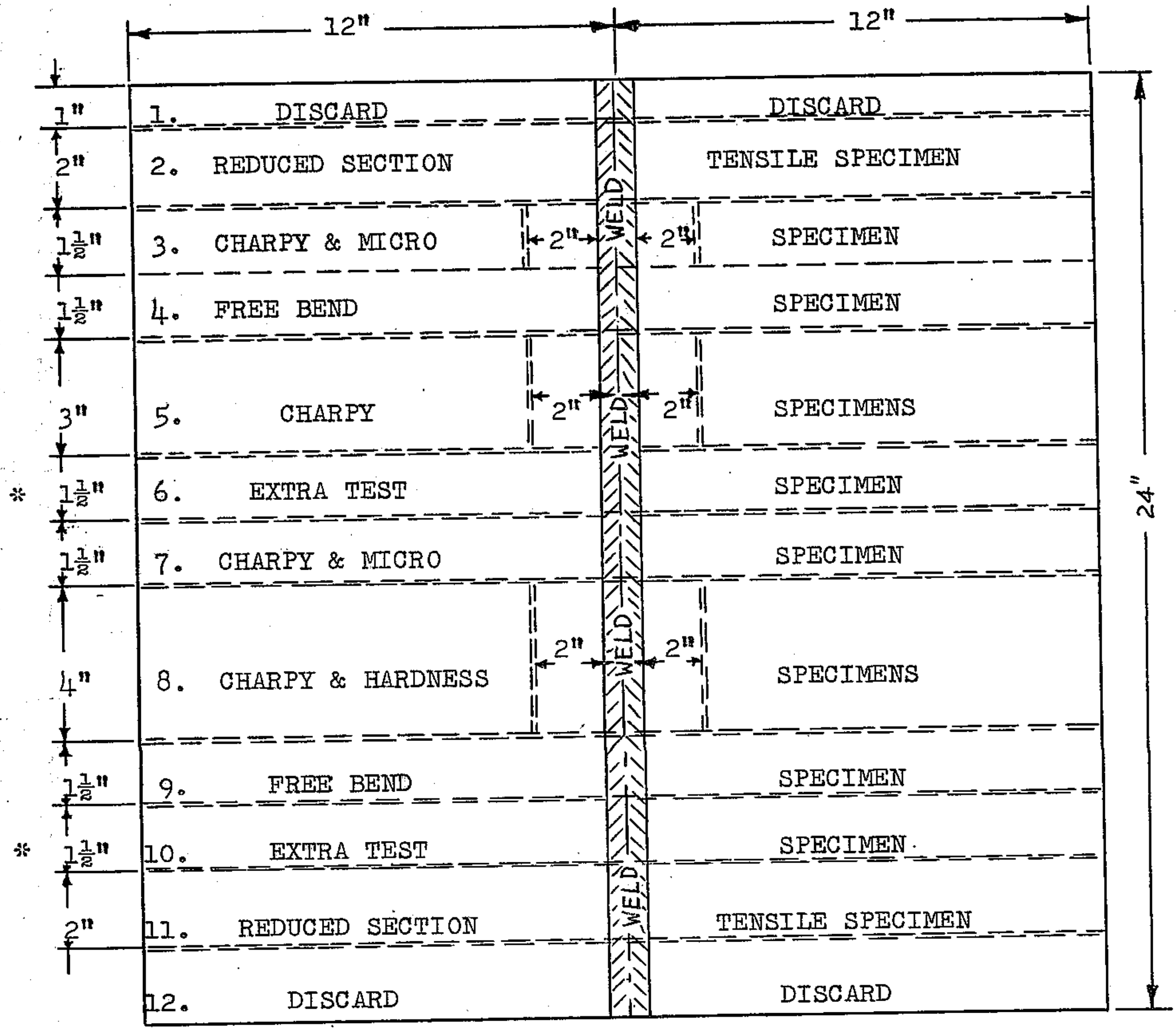
EXHIBIT OF TESTS

PERFORMED ON EACH PLATE

Exhibit 1

PLAN FOLLOWED IN CUTTING SPECIMENS

From ½" CARILLOY T-1 STEEL TEST PLATES



* Extra Test Specimens for Proof Testing.

PLAN FOLLOWED IN CUTTING SPECIMENS

From 1" and $1\frac{1}{2}$" Carilloy T-1 Steel Test Plates

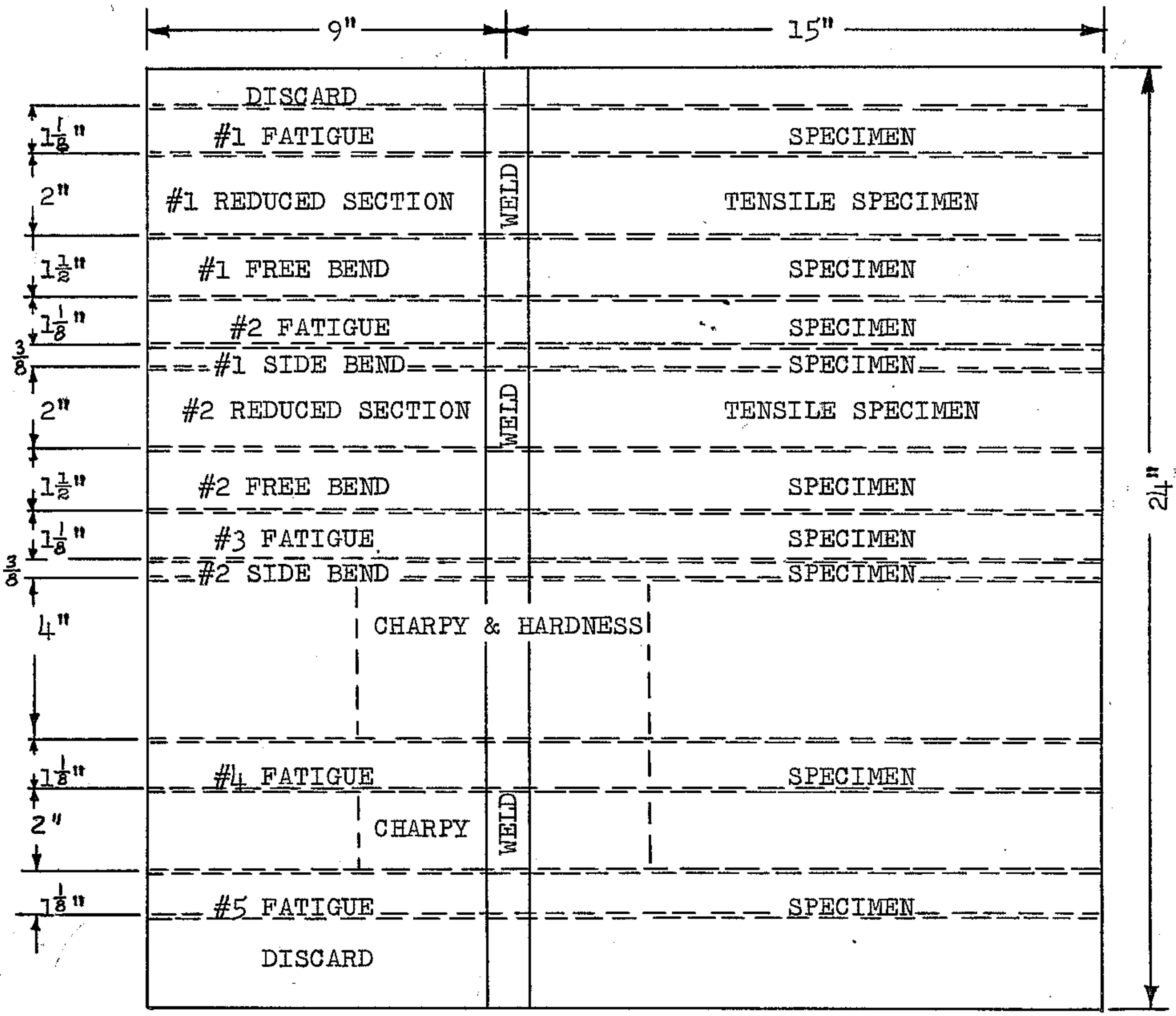
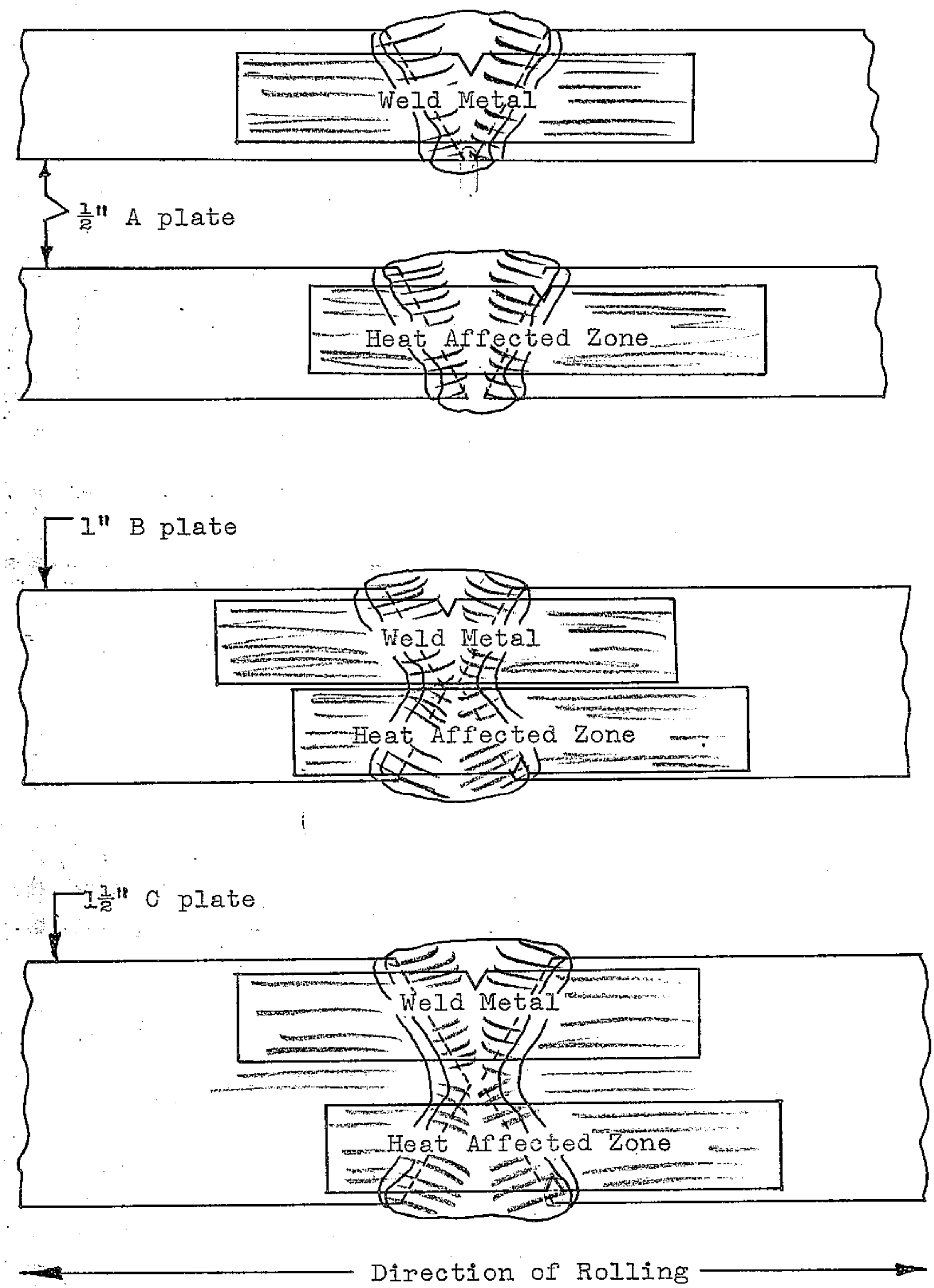
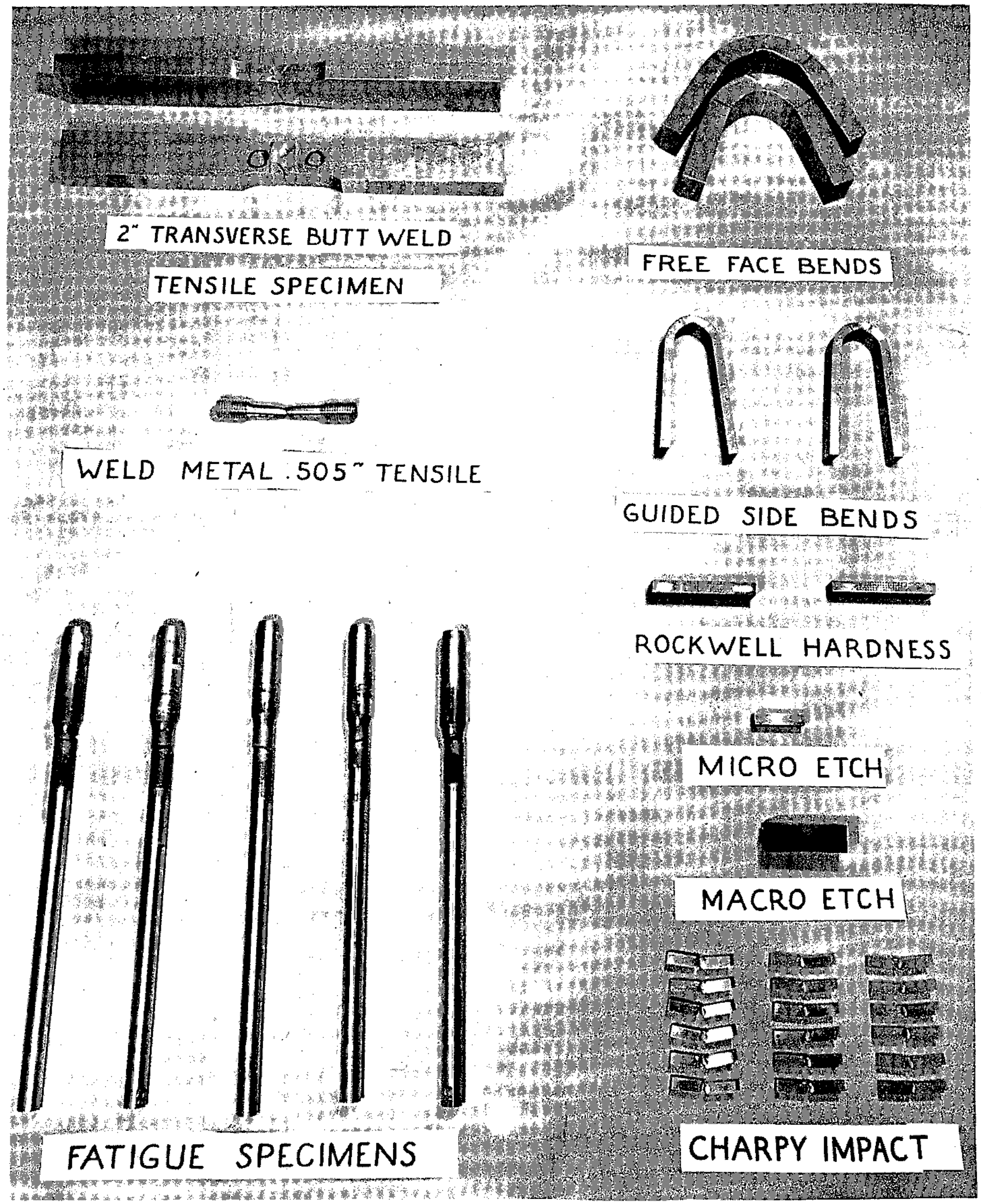


Exhibit 3

LOCATION OF CHARPY V-NOTCH SPECIMENS AS TO WELD

METAL AND HEAT AFFECTED ZONE





Picture of Test Specimens from each T-1 Sample Plate
(no fatigue tests on $\frac{1}{2}$" plate)

GRAPHIC COMPARISONS

OF THE

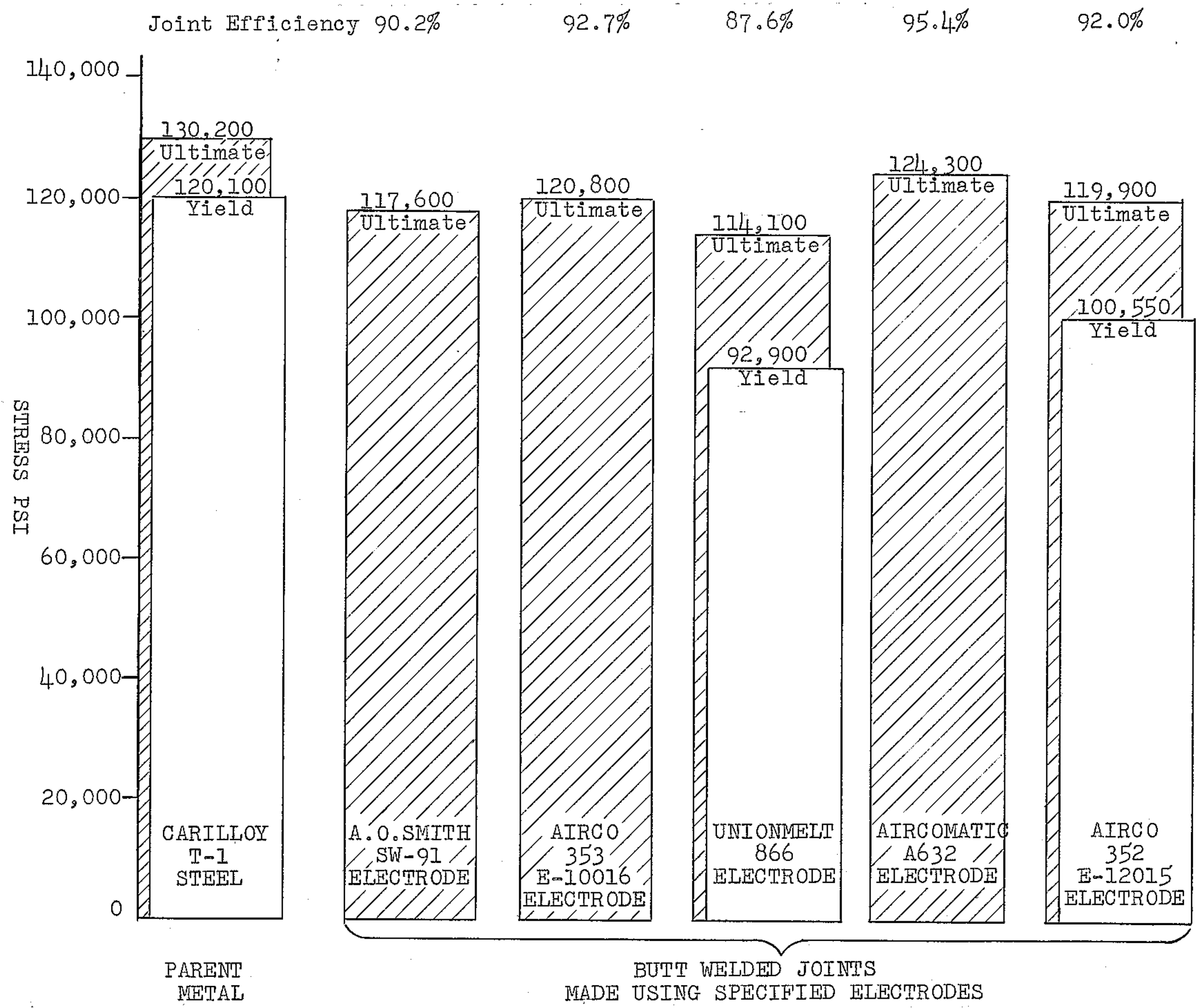
PHYSICAL PROPERTIES

OF THE

VARIOUS WELDS

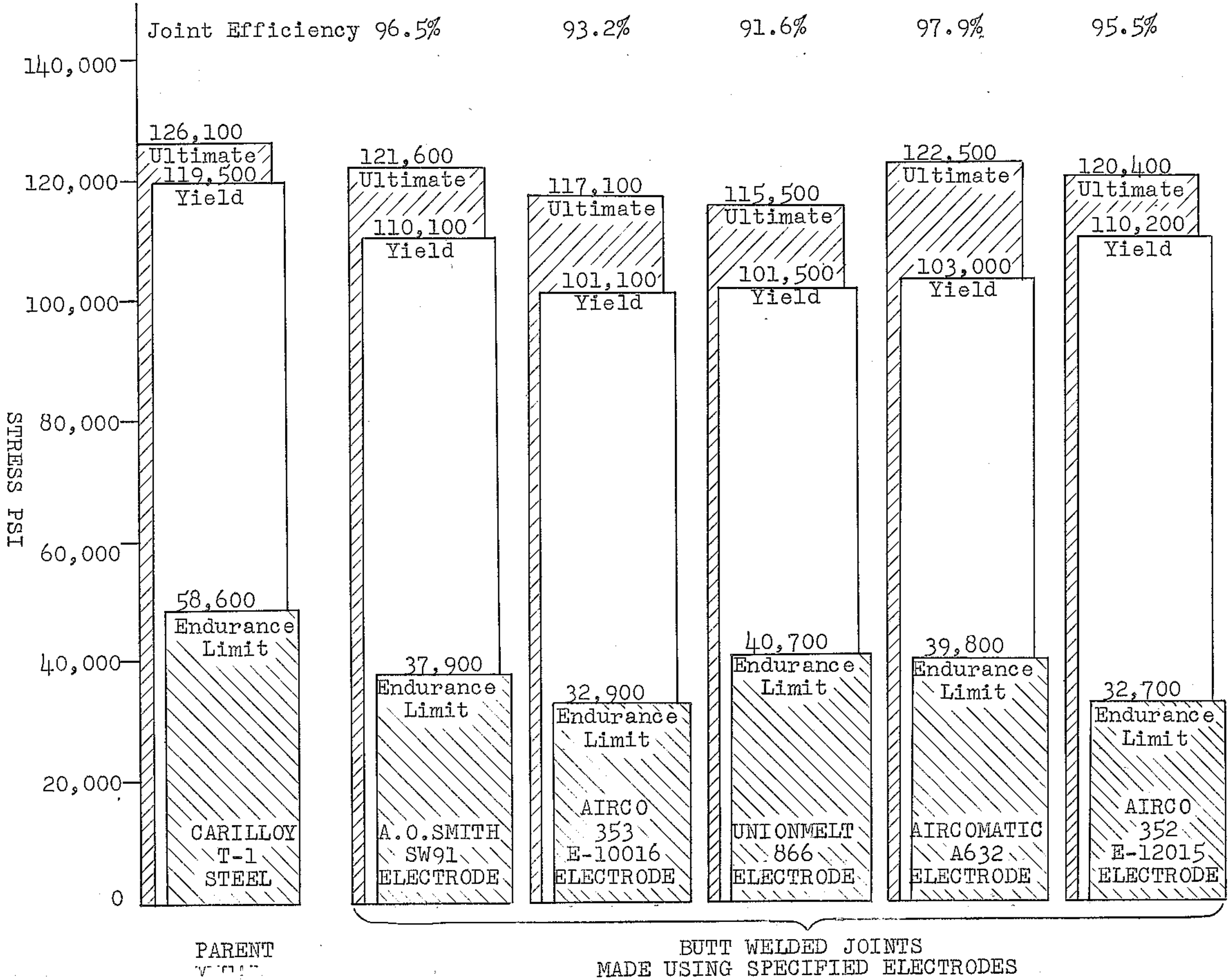
[illegible]

TENSILE STRENGTHS AND JOINT EFFICIENCIES
OF BUTT WELDED JOINTS IN ½" CARILLOY T-1 PLATES

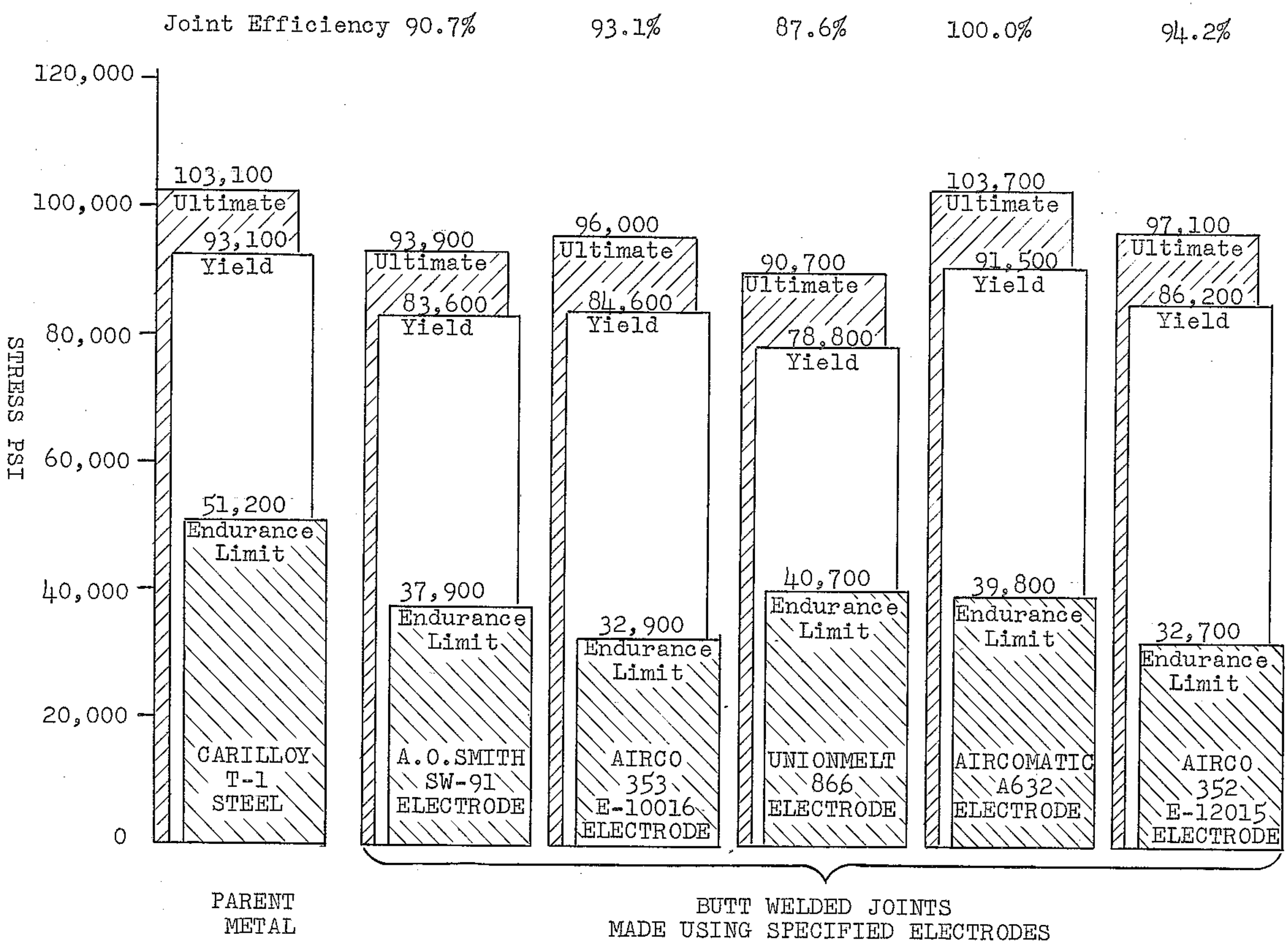


TENSILE STRENGTHS AND JOINT EFFICIENCIES

OF BUTT WELDED JOINTS IN 1" CARILLOY T-1 PLATES



TENSILE STRENGTHS AND JOINT EFFICIENCIES
OF BUTT WELDED JOINTS IN $1\frac{1}{2}$" CARILLOY T-1 PLATES



PERCENT ELONGATION OF STRAP TENSILES

FOR BUTT WELDED JOINTS IN CARILLOY T-1 PLATES

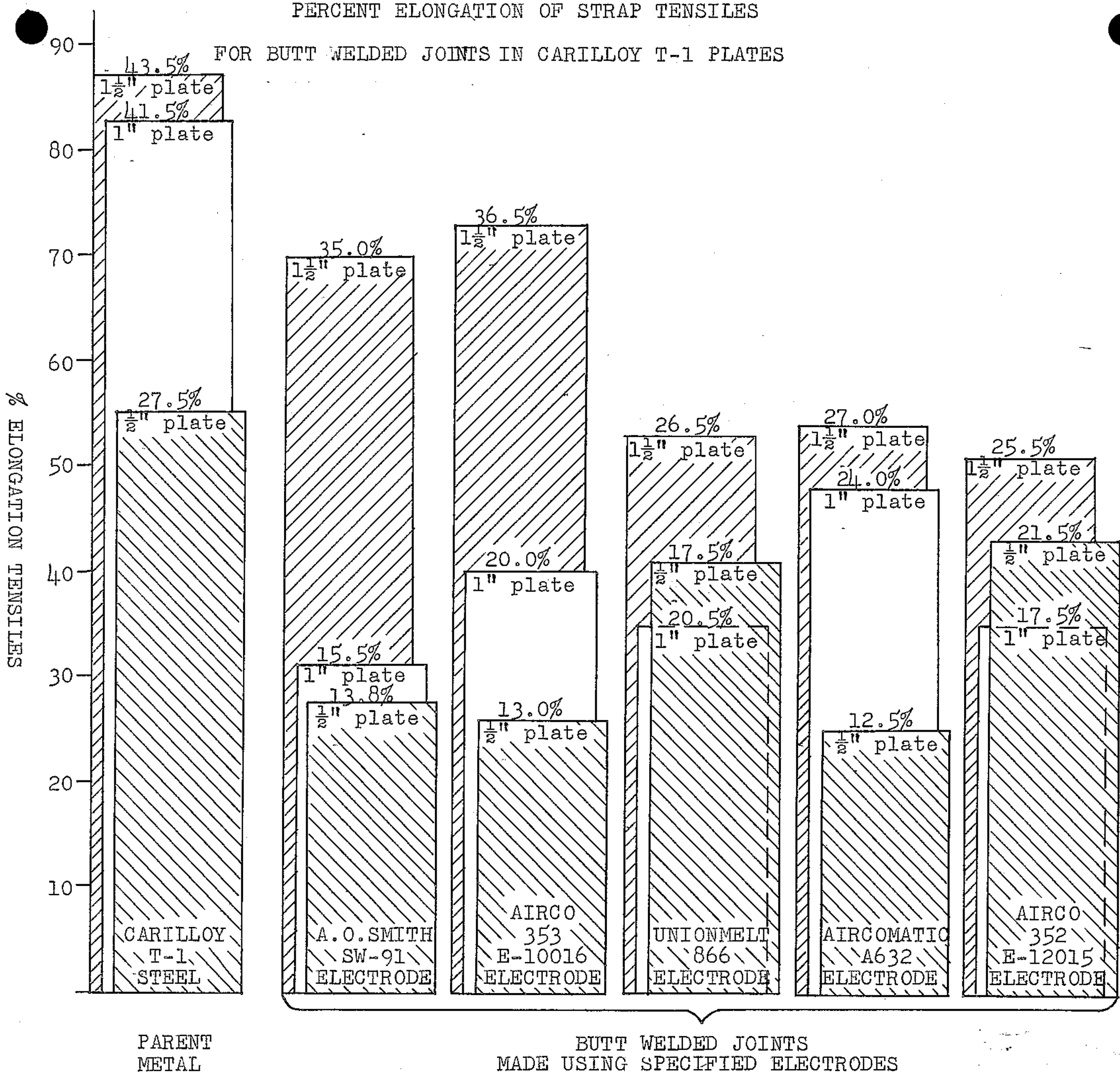
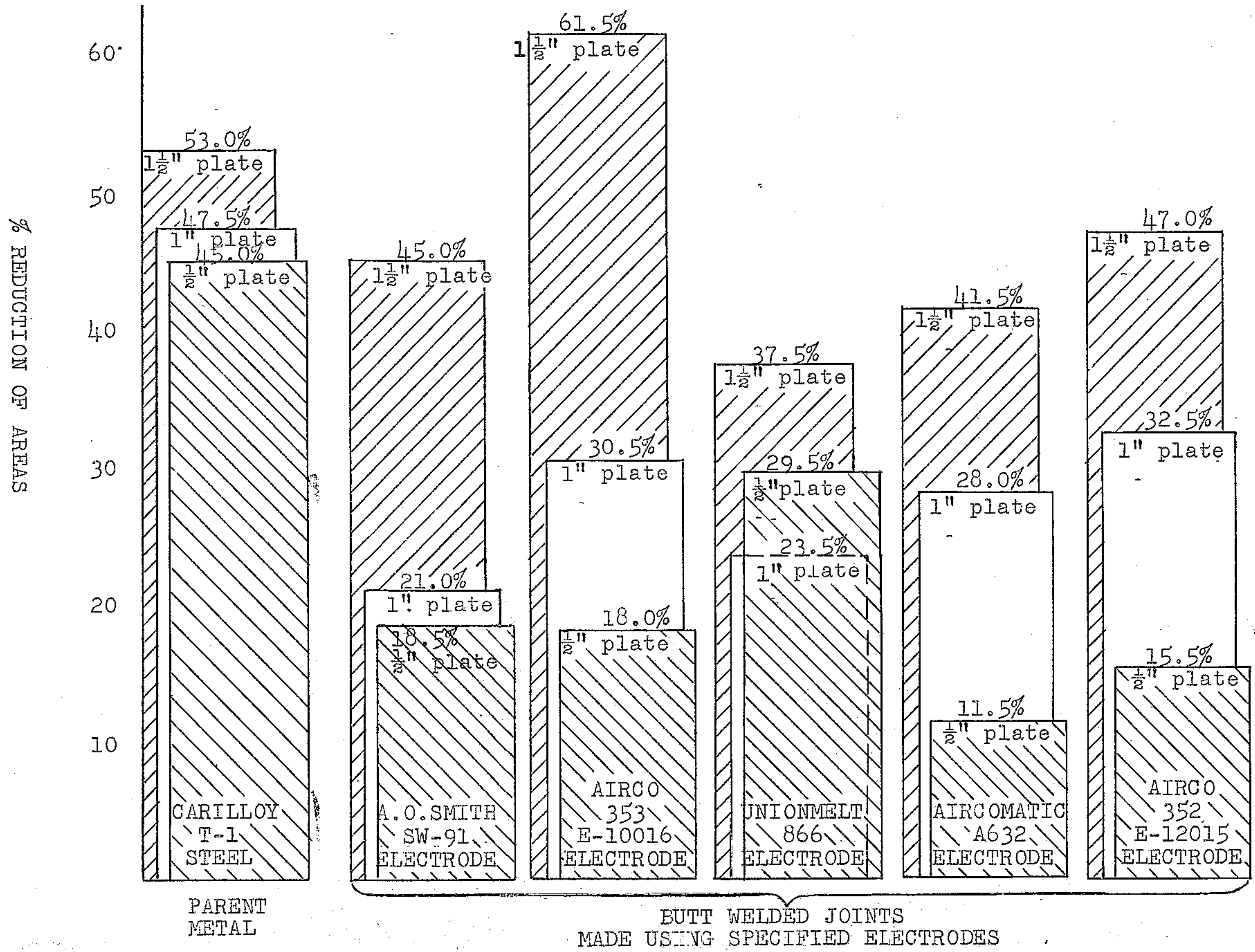


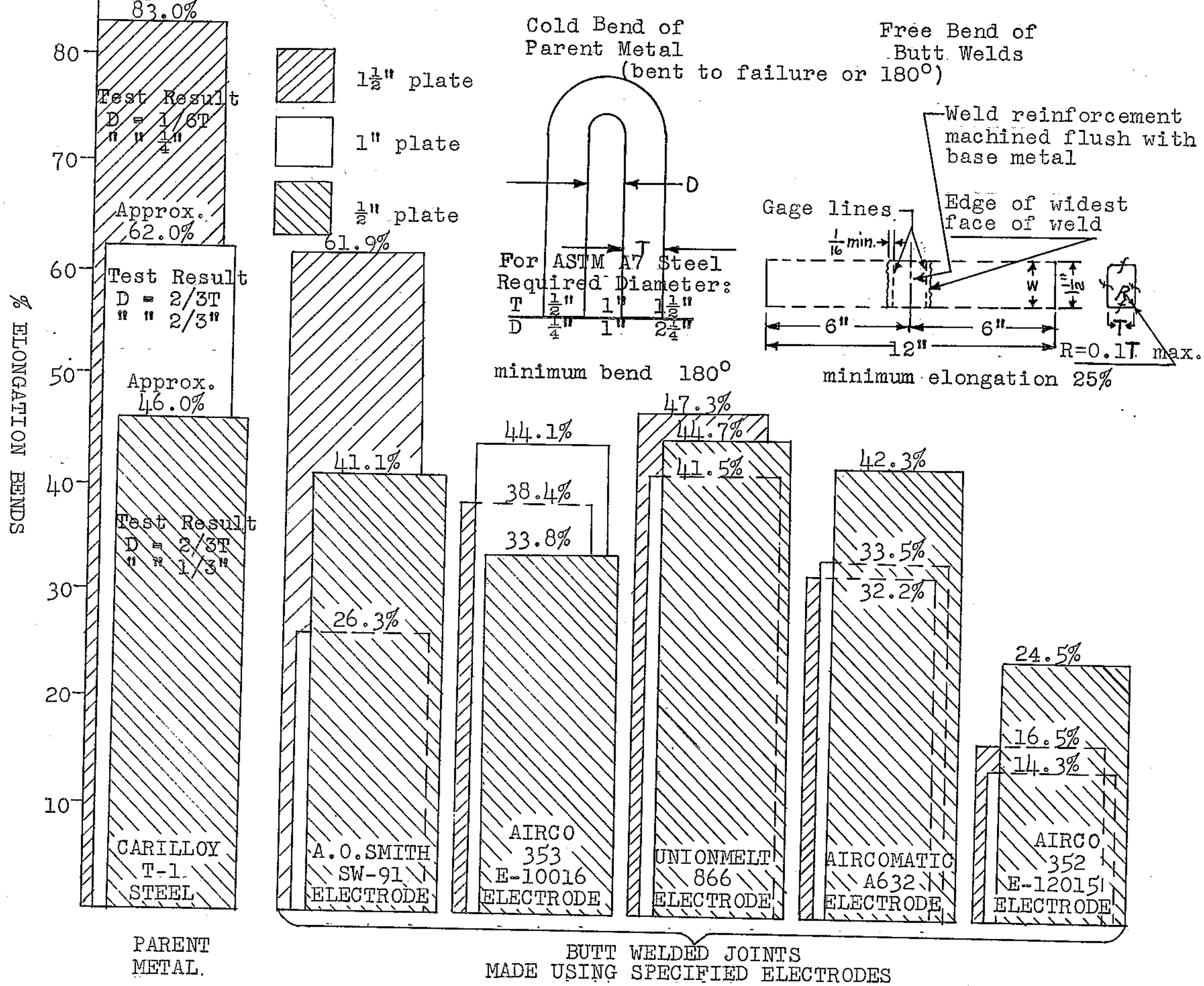
Exhibit 8 A

PERCENT REDUCTION OF AREAS OF STRAP TENSILES

FOR BUTT WELDED JOINTS IN CARILLOY T-1 PLATES



PERCENT ELONGATION OF FREE BENDS FOR BUTT WELDED JOINTS IN CARILLOY T-1 PLATES



CHARPY IMPACT ENERGY

FOR BUTT WELDED JOINTS IN CARILLOY PLATES

(0° Fahrenheit, "V" notch)

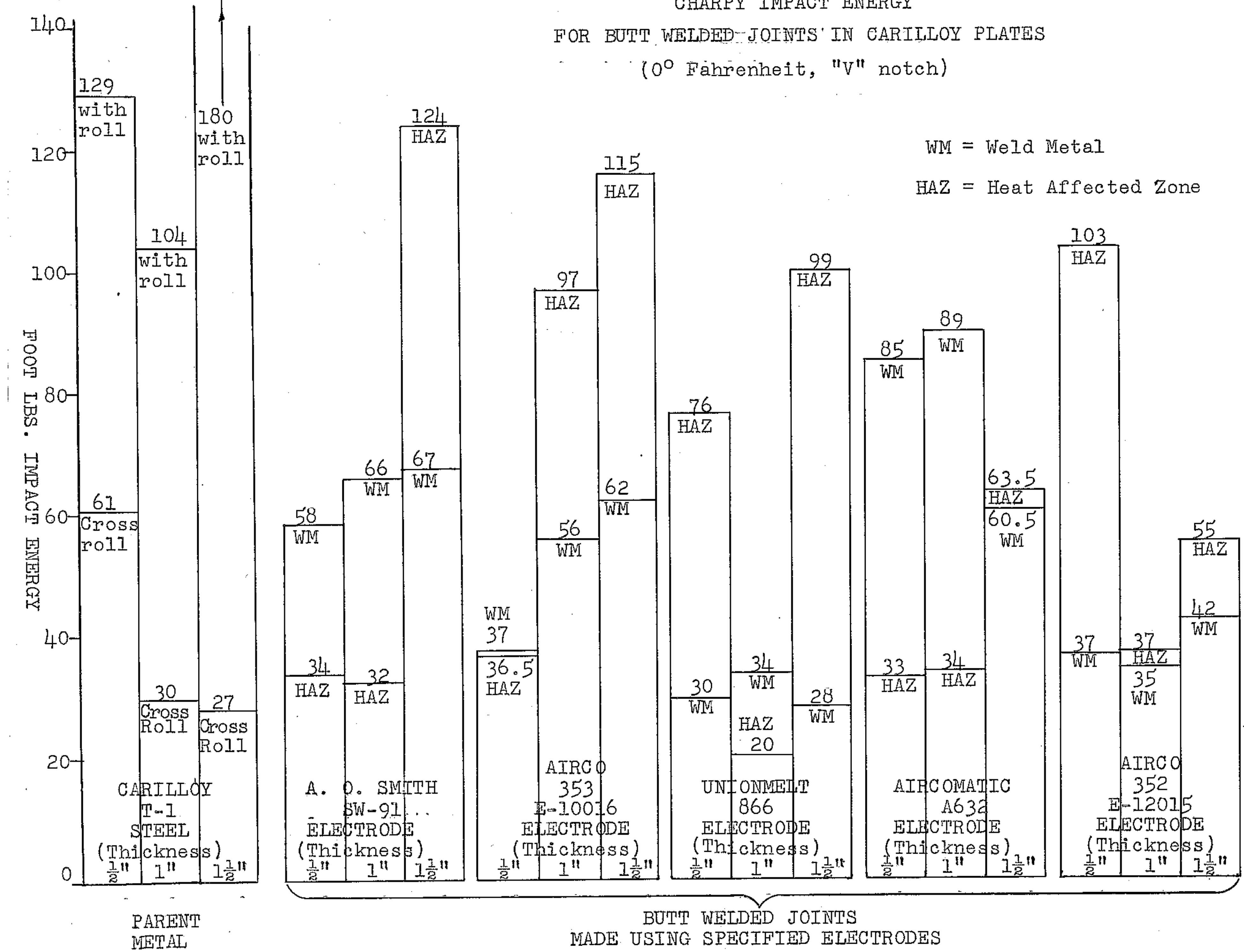
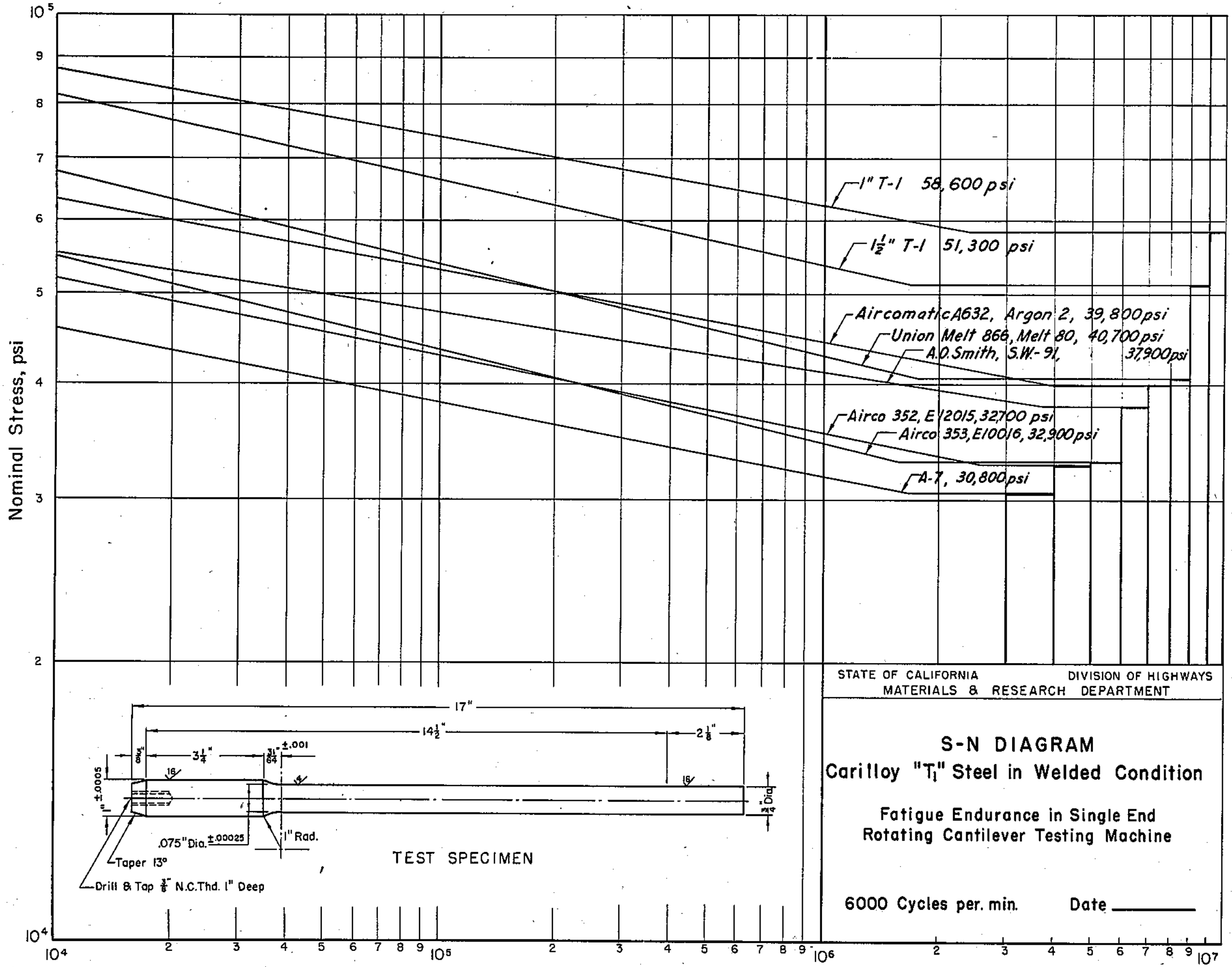


EXHIBIT NO. 11



SUMMARY SHEETS OF RESULTS FOR

INDIVIDUAL TESTS

Sheet 1 Parent Metal and A.O. Smith Welds

Sheet 2 Airco 353 and Unionmelt Welds

Sheet 3 Aircomatic Welds

Sheet 4 Airco 352 Welds

VIII APPENDIX

SECTION B

PHOTOGRAPHS

OF

PHYSICAL TESTS

ON

T-1 STEEL

(Mill Test Report Included)

2GM-221-REV.-153

UNITED STATES STEEL CORPORATION

OPERATING DEPARTMENT—METALLURGICAL DIVISION

Pittsburgh DISTRICT FILE NO.

Report of CHEMICAL and PHYSICAL Tests of O.H. U.S.S.T-1 Steel Plates Homestead Works March 7, 19 55G

Charged to U.S.Steel Co. Shipping Notice 13-2-04892-2/28-Dup.

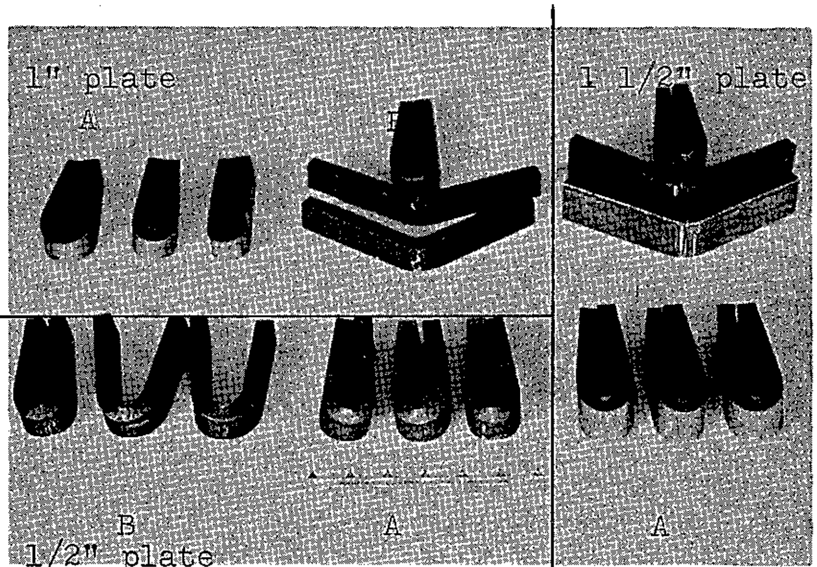
Shipped to Same, Pittsburgh, Penna. Car Number INTERNATIONAL FRT. FORWARDING CO.

Customer's Order No. and Date	Mill Order No.	Heat No.	Slab No.	ANALYSIS C	Mn	P	S	SI	NI	CR	Test Piece Cut From	Y.S.E.U.L. lbs. per sq. in.	Tensile Strength lbs. per sq. in.	Elong. In 2" %	Red. of Area %	Bend Test
1/3/55	UF-829	74P577	147682	.15	.86	.013	.020	.21	1.01	.46	1/2	100100	112550	31.5	63.4	
				CU-.29	V-.06	MO-.45		Boron-.002								
		74S022	W45451	.15	.75	.014	.018	.21	.87	.50	1"	108800	118300	23.0	69.8	
				CU-.34	V-.04	MO-.48		Boron-.003								
		67P599	150687	.15	.80	.018	.018	.19	.97	.41	1-1/2	95720	107300	24.0	72.6	
				CU-.36	V-.04	MO-.41		Boron	.002							
				Plates & Test Spec. Quenched & Tempered												

Exhibit 13

M.Brezin Chief Met.

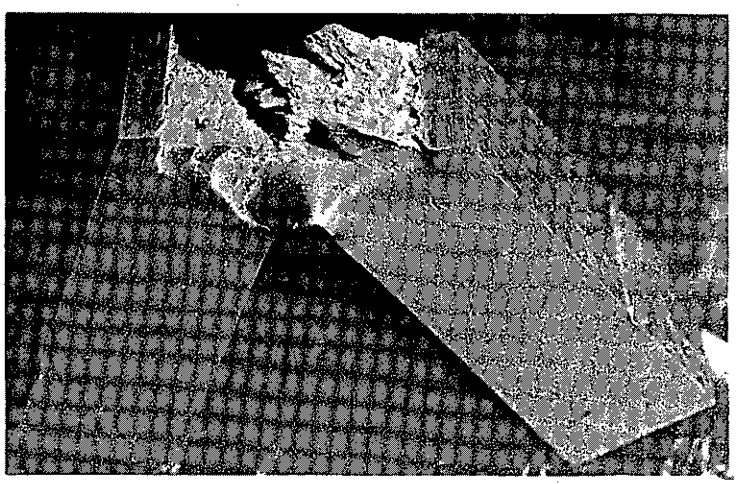
We hereby certify that the above figures are correct as contained in the records of the company



Cold bend tests of flame cut and machine cut edges. Note failure of flame cut edges. 1/2" plate was bent to side.

A - Machine cut

B - Flame cut



Note fibrous appearance of impact fracture typical of tough parent metal

CARILLOY T-1 STEEL

PHOTOGRAPHS

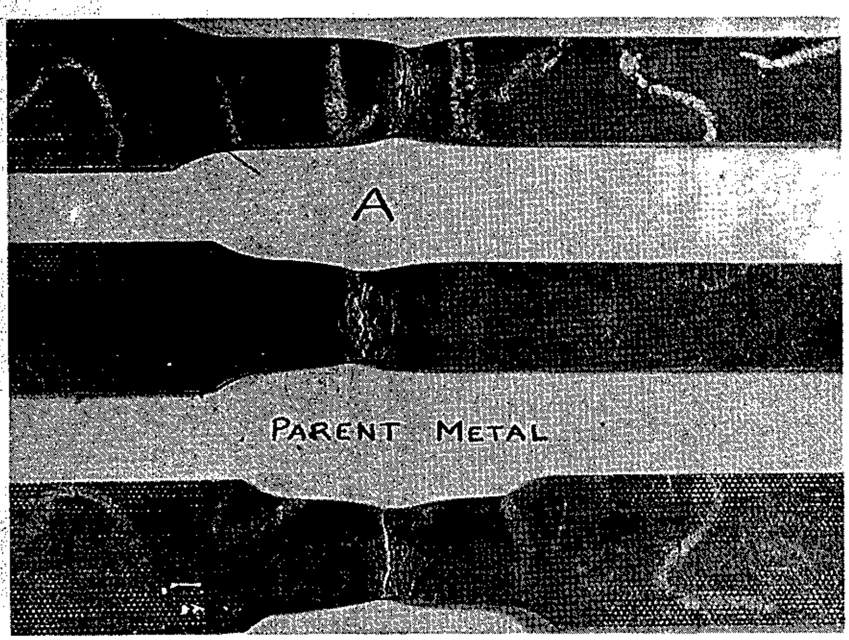
OF

TESTS

ON

1/2" PLATE

Exhibit 15



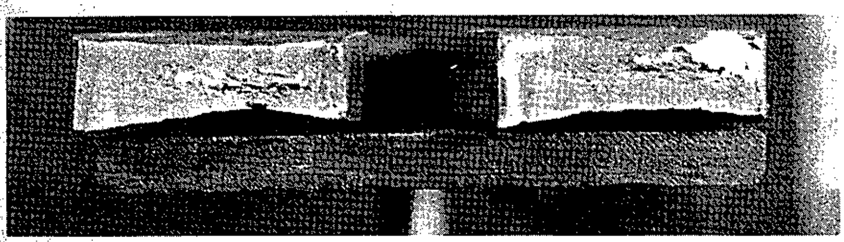
A

B

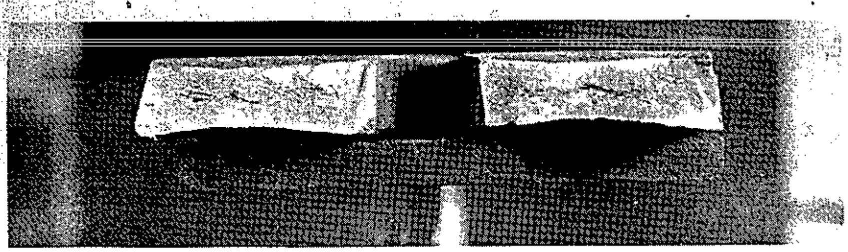
C

Parent Metal
8" and 2"
Strap tensiles
taken from
1/2" plate

	Yield	Ultimate	Elong.	Red Area
A	116,300psi	127,200psi	11%@8"	45%
B	118,300psi	130,800psi	9.5%@8"	42%
C	125,600psi	132,700psi	27.5%@2"	48%

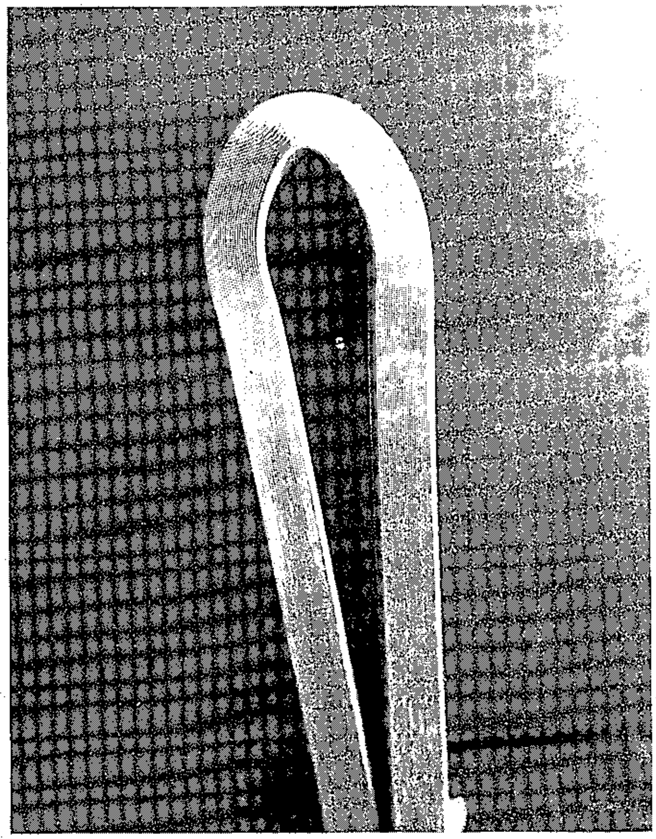


End View of
Parent Metal
Tensile Failure
1/2" plate



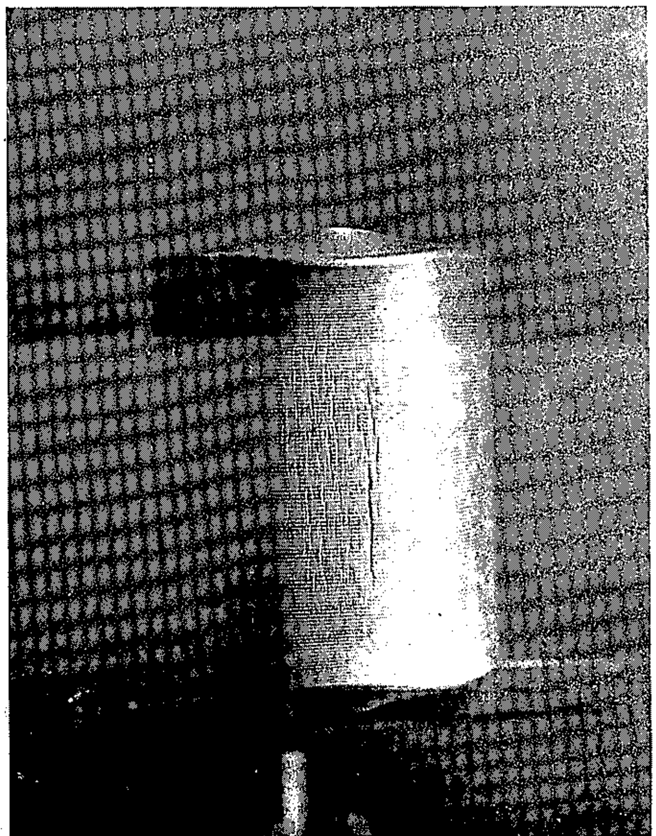
End View of
Parent Metal
Tensile Failure
1/2" plate

Exhibit 16



Side view

Cold bend test 1/2" Carilloy T-1 plate



Face view

Note openings in bend face

[illegible]

CARILLOY T-1 STEEL

PHOTOGRAPHS

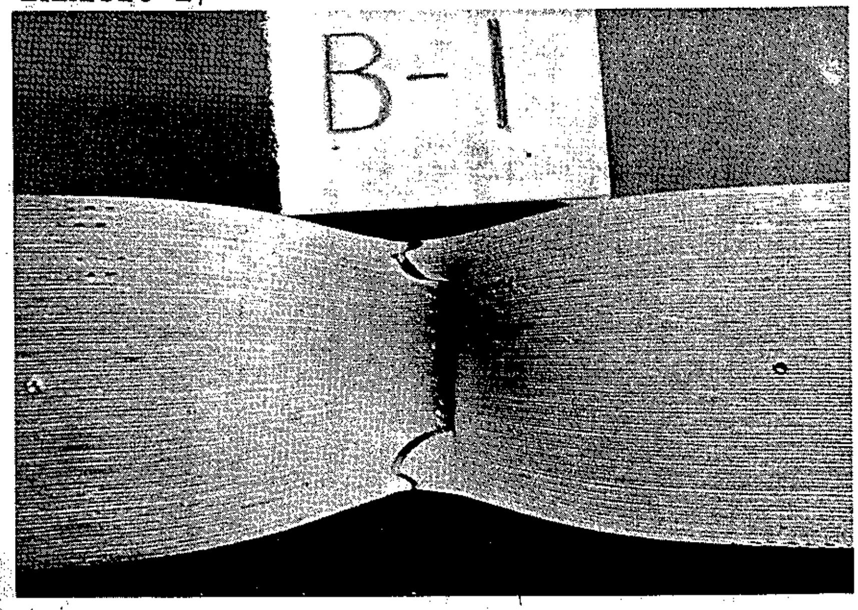
OF

TESTS

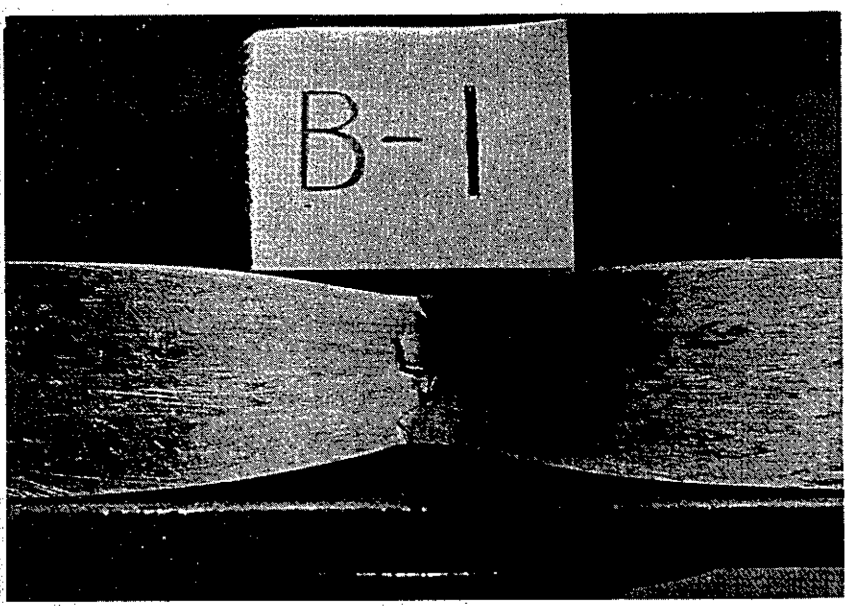
ON

1" PLATE

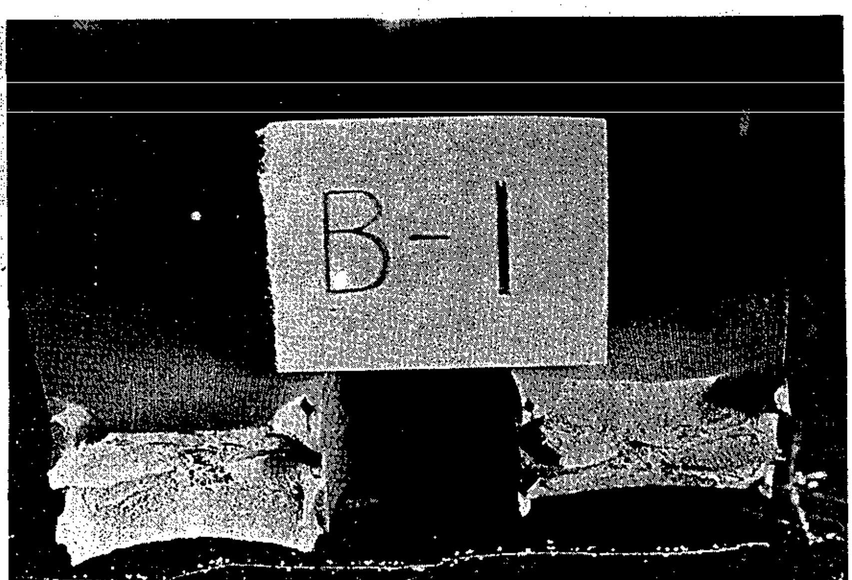
Exhibit 17



Face view



Side view

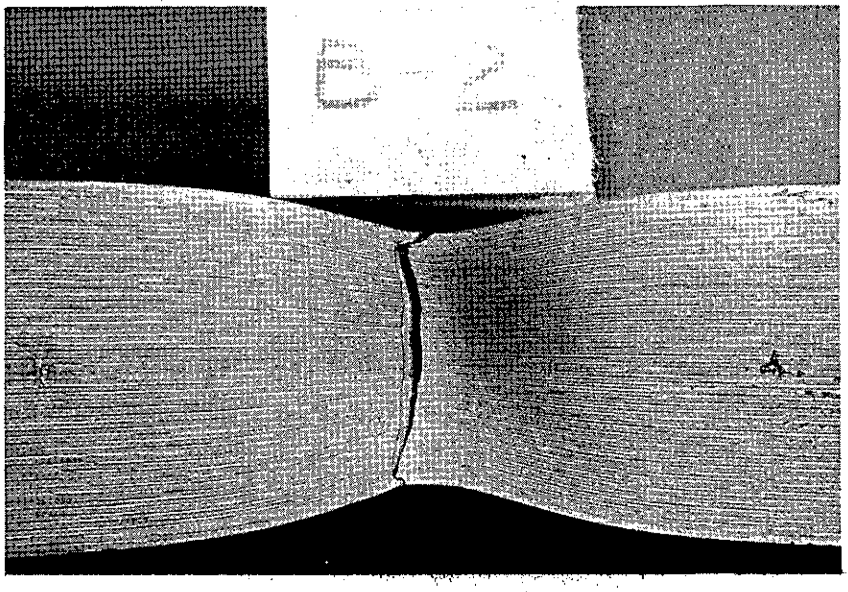


End view

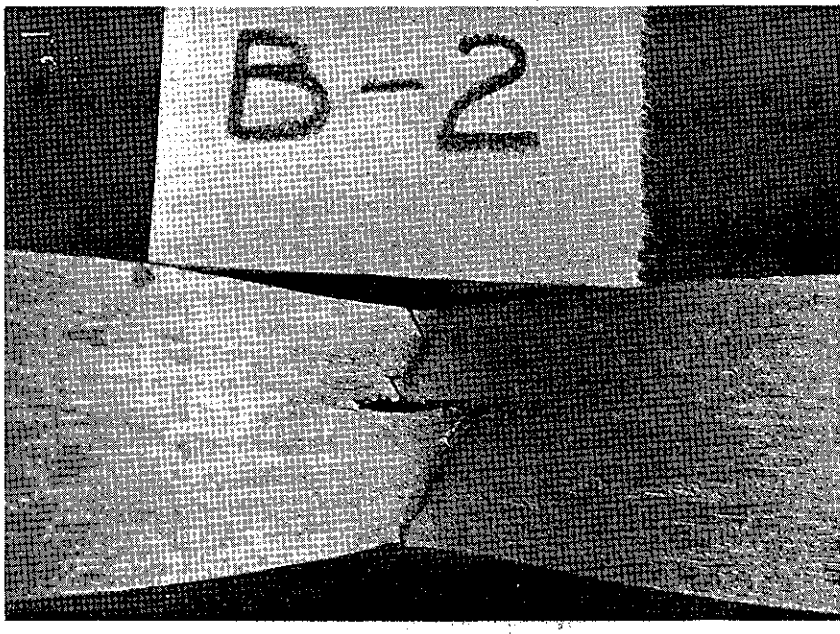
2" strap tensile
from 1" Carilloy
T-1 plate

Note parallel shear
in ductile fracture

Yield Strength	116,100
Ultimate "	122,800
Elongation	41%@2"
Red Area	57%



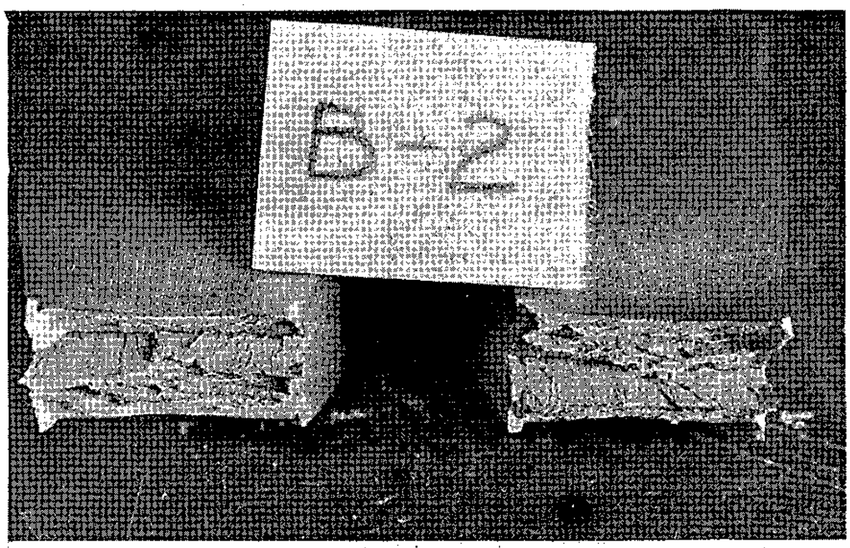
Face view



Side view

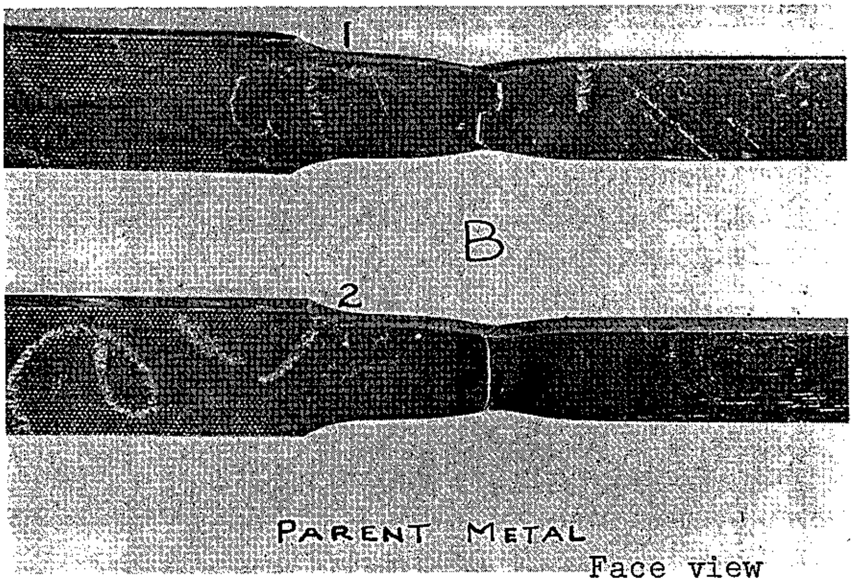
2" strap tensile from
1" Carilloy T-1 plate
(note parallel shear
in ductile fracture)

Yield Strength	114,500psi
Ultimate "	123,400psi
Elongation	42%@2"
Red Area	58%



End view

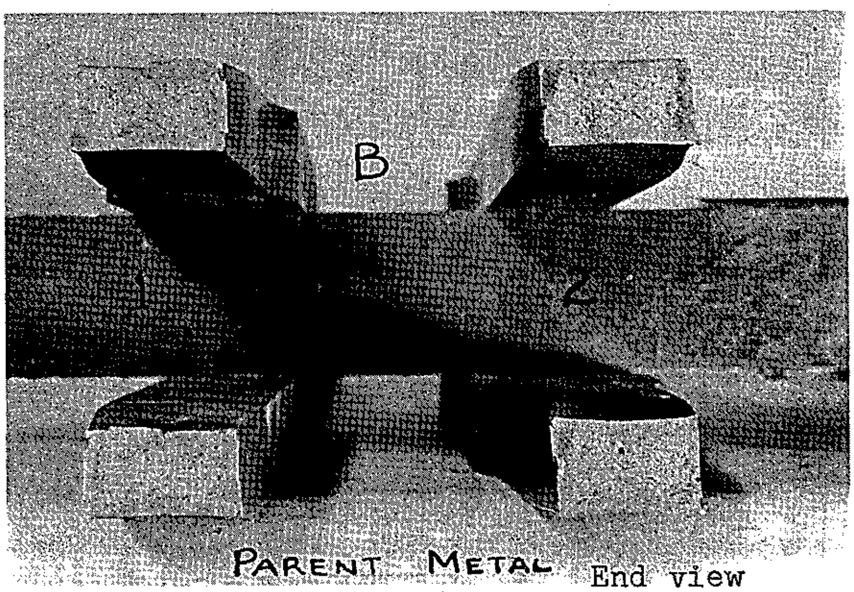
Exhibit 19



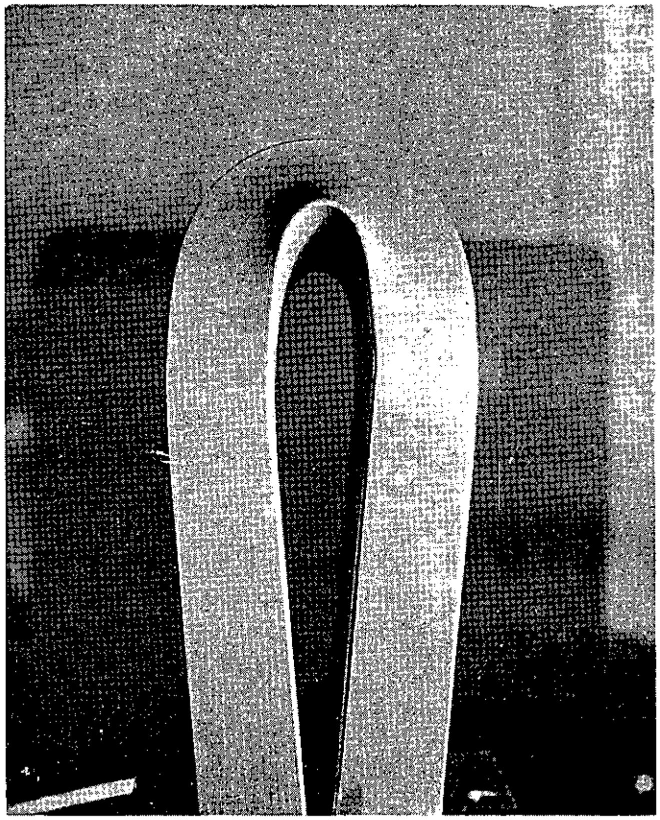
Face view

8" strap tensile specimens from 1" plate (note rolling structure visible in these fractures)

	Yield Strength	Ultimate Strength	%2" Elongation	Red Area
1.	123,000psi	127,600psi	11.%	37%
2.	120,300psi	128,100psi	11.5%	38%

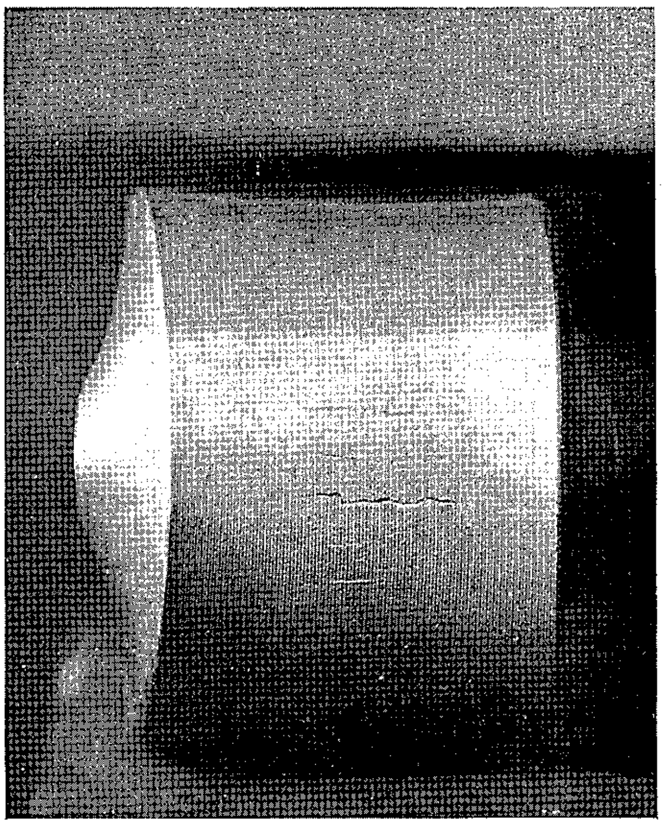


End view



Cold bend test
1" Carilloy T-1 plate

Side view



Note openings in bend face

Face view

CARILLOY T-1 STEEL

PHOTOGRAPHS

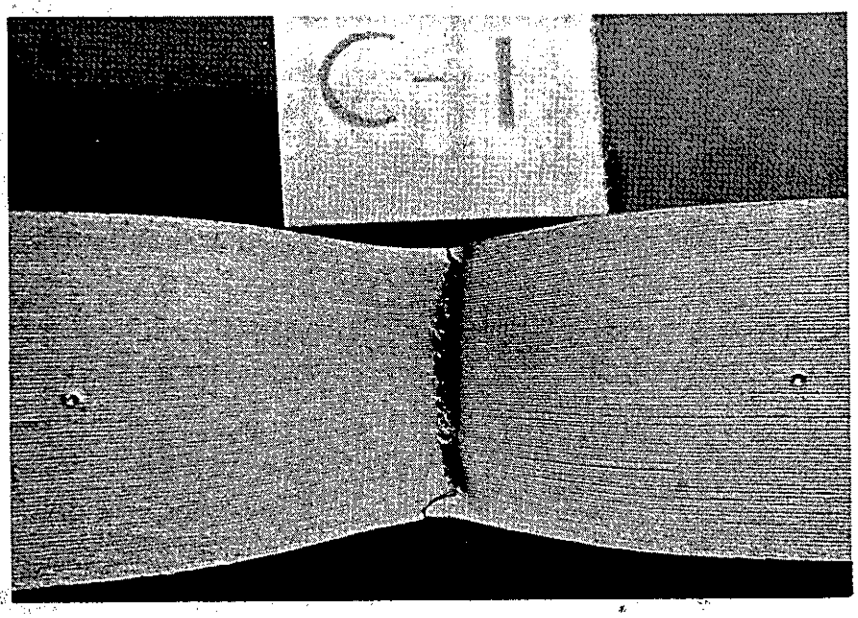
OF

TESTS

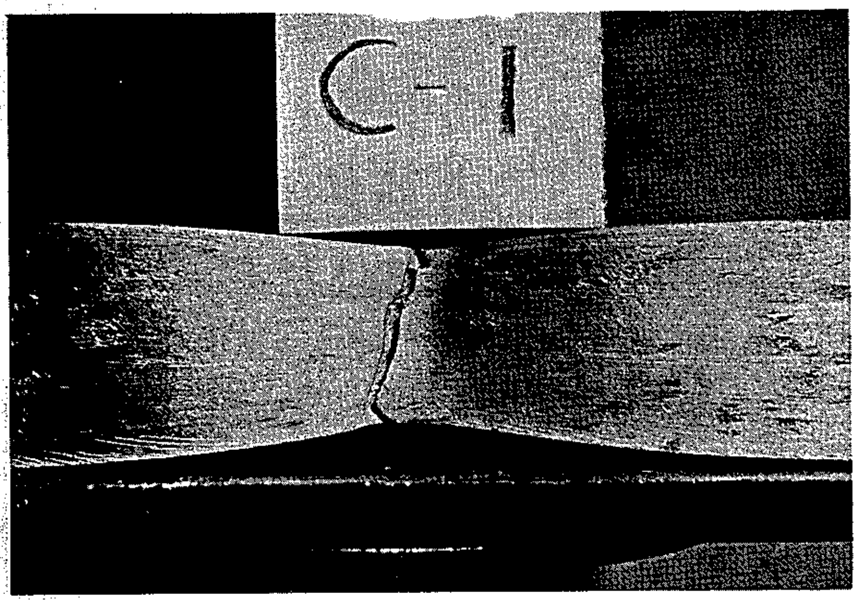
ON

1 1/2" PLATE

Exhibit 21



Face view



2" strap tensile
1 1/2" Carilloy
T-1 plate

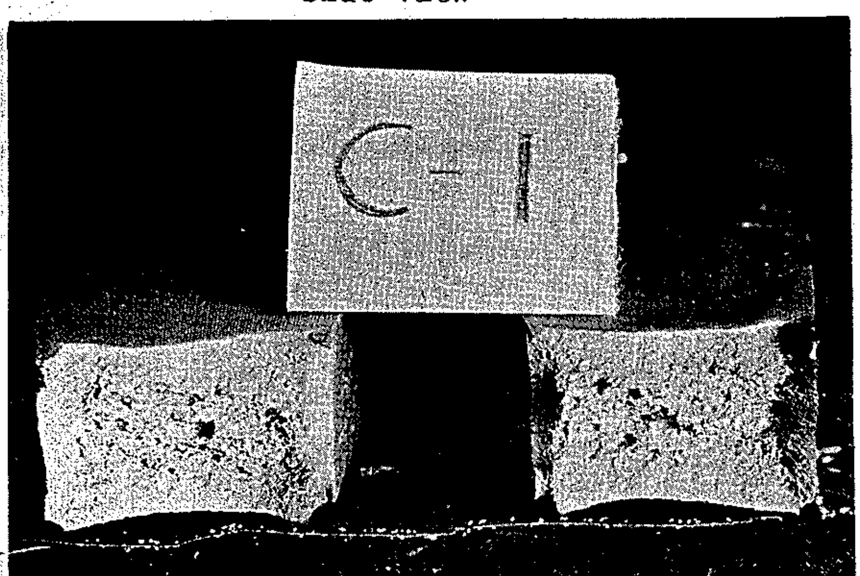
Yield
90,000psi

Ultimate
100,300psi

Elongation 39%@2"

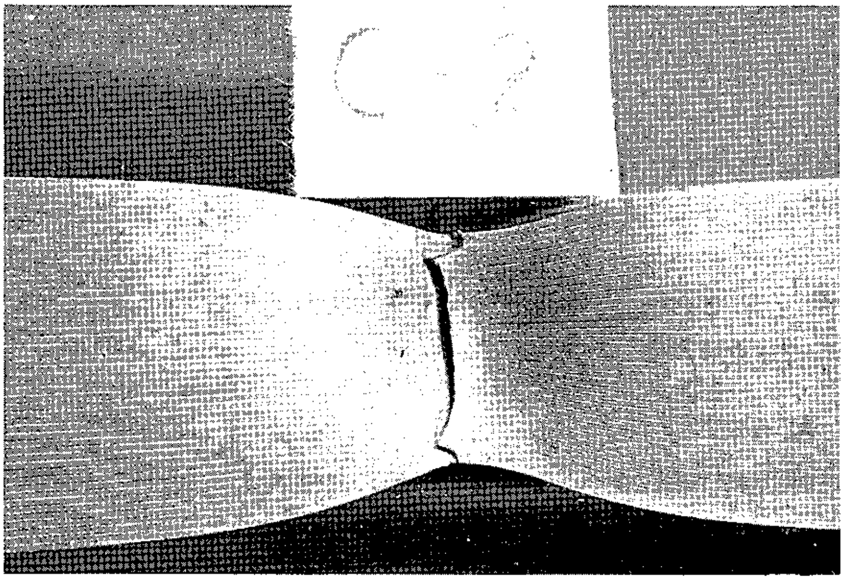
Red Area 49%

Side view

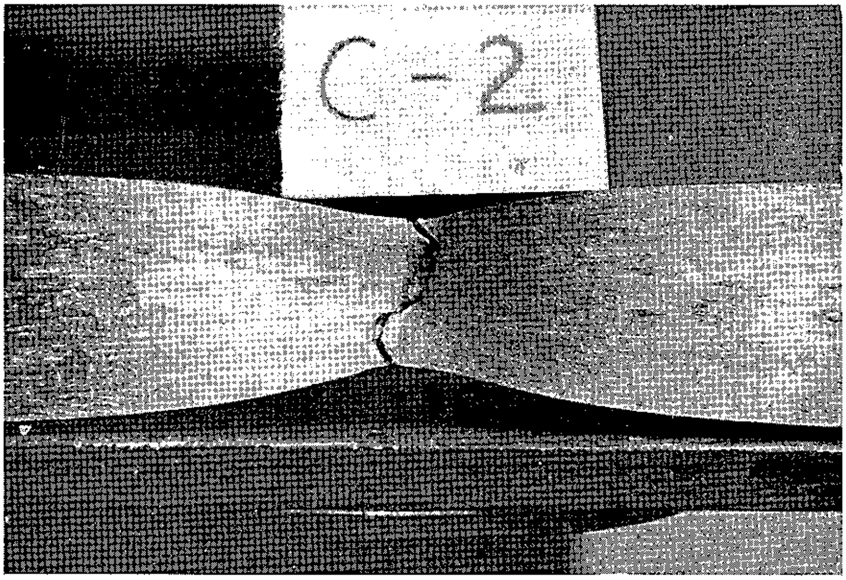


End view

Note rolling
structure



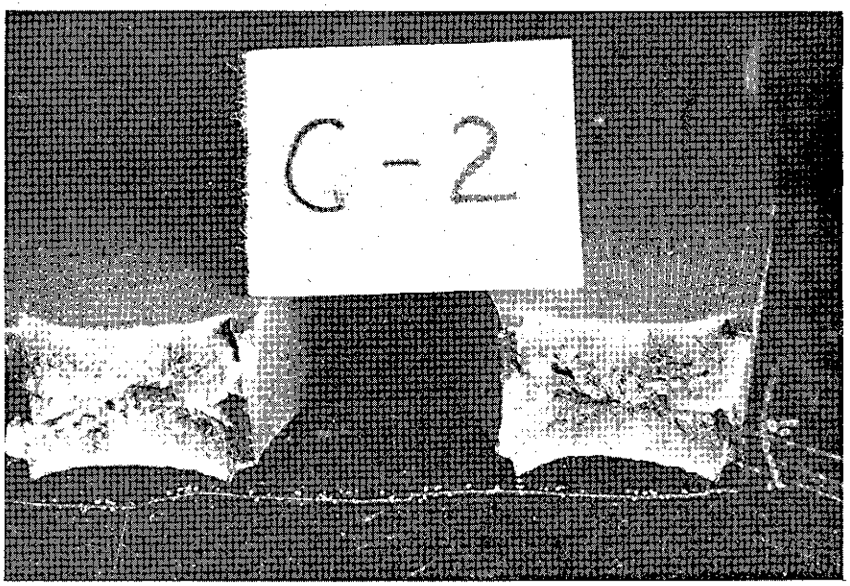
Face view



Side view

2" strap tensile from 1 1/2" Carilloy T-1 plate

Yield Strength 90,600psi
Ultimate " 102,800psi
Elongation 48%@2"
Red Area 61%



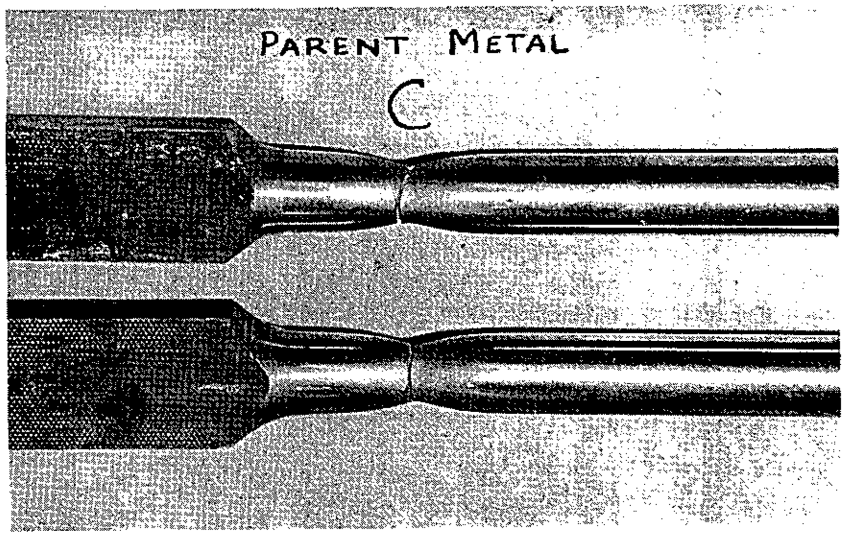
End view

(note shear)

Exhibit 23

A.

B.

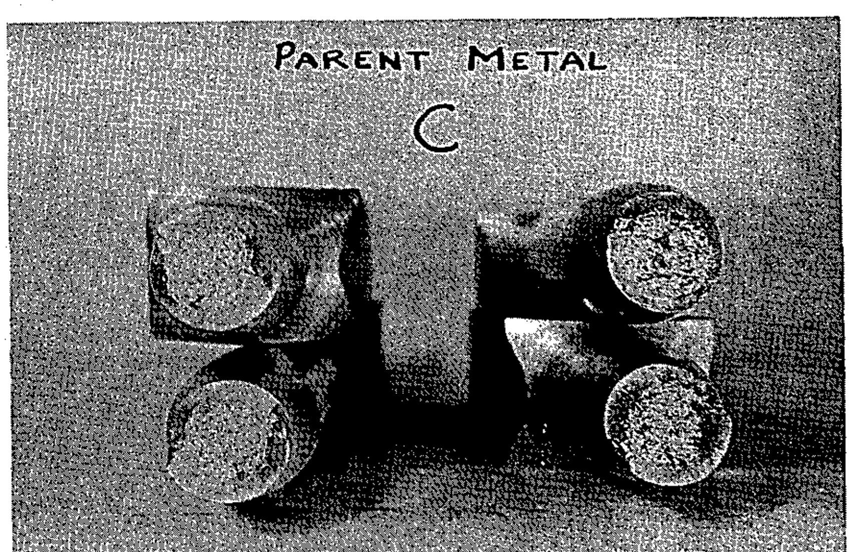


Side view

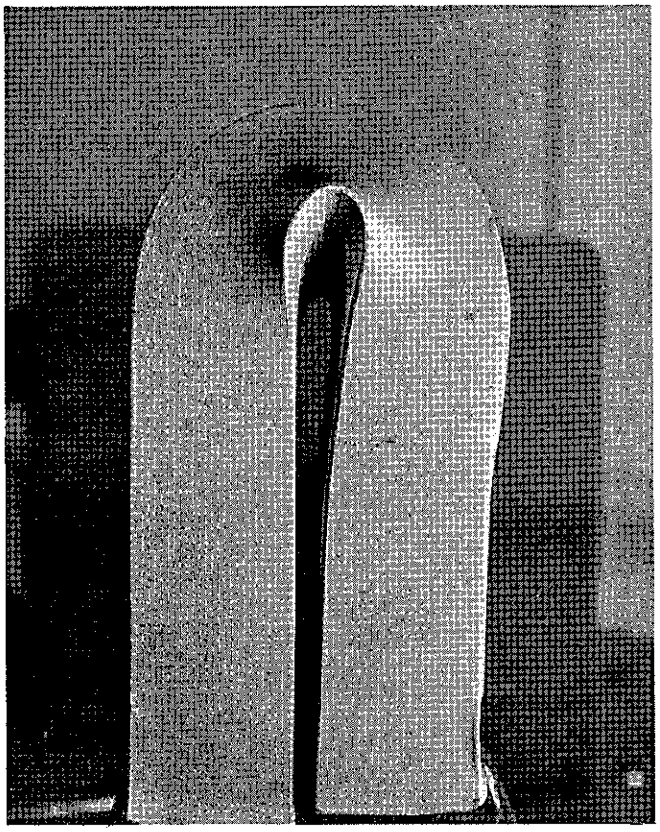
8" bar tensile from 1 1/2" plate

	Yield Strength	Ultimate Strength	8" % Elongation	% Red Area
A.	96,000psi	106,000psi	14%	50%
B.	97,500psi	106,100psi	14%	53%

End view

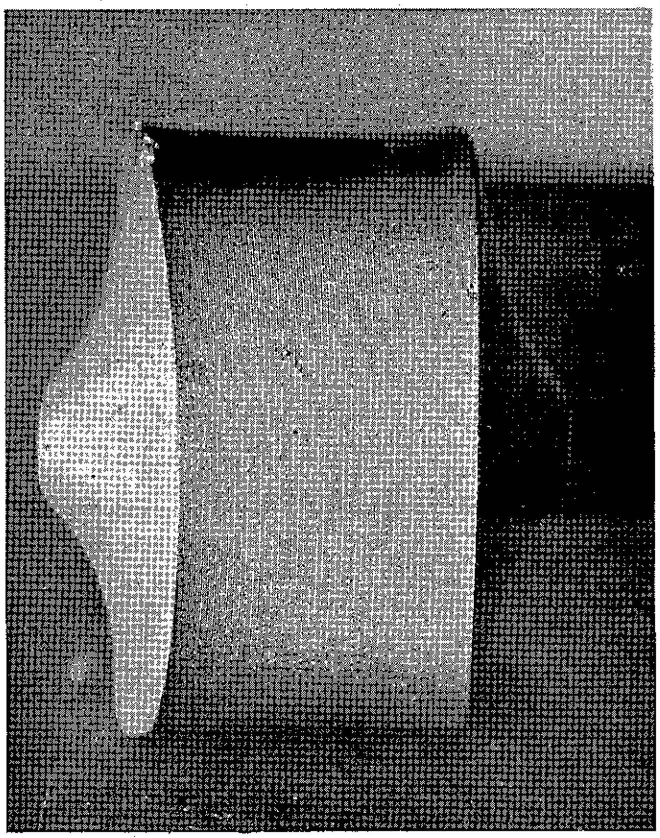


A. B.



Side view

Cold bend test
1 1/2" Carilloy T-1 plate



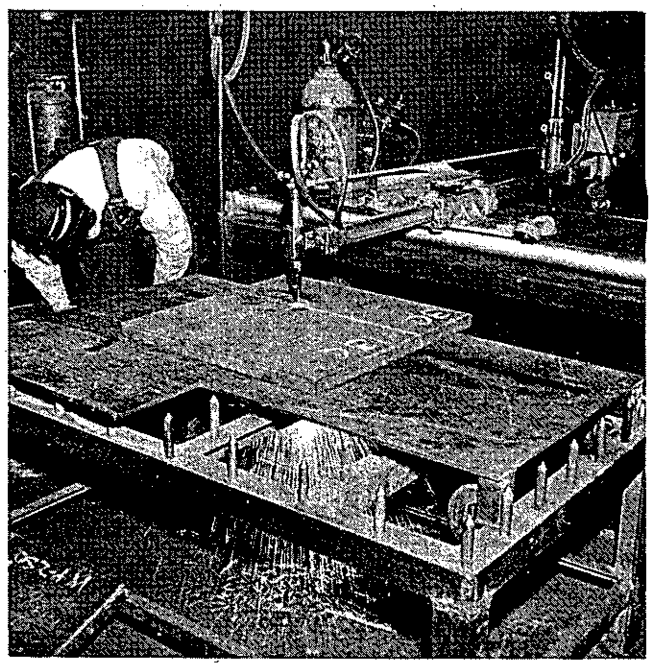
Face view

VIII APPENDIX

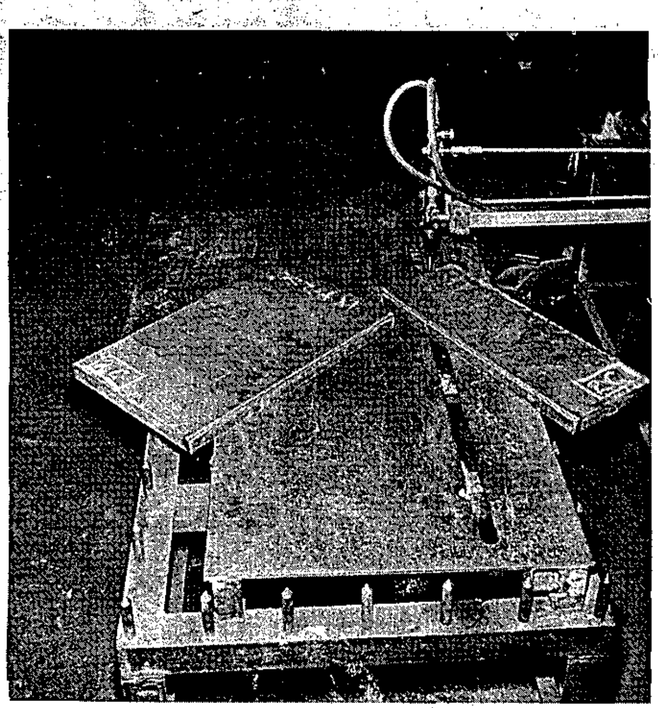
SECTION C

THE
FLAME CUTTING AND BEVELING
OF
T-1 STEEL PLATE

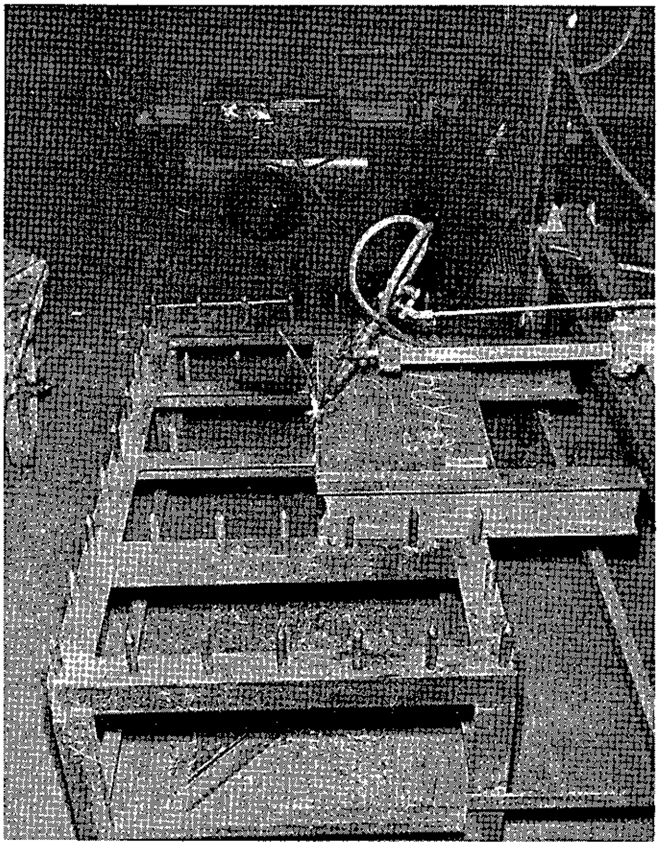
Exhibit 25



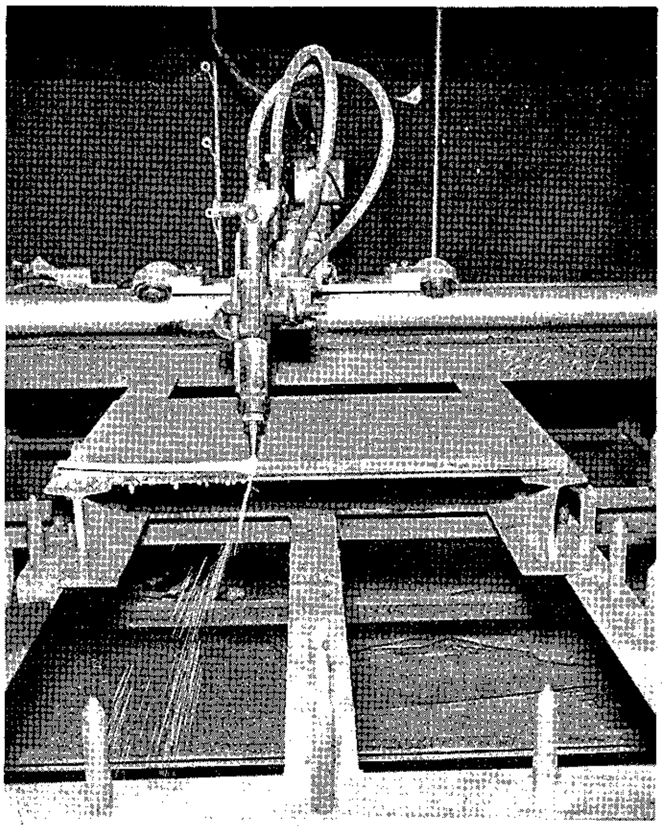
The Carilloy T-1 test plates were flame-cut with an Airco automatic cutting machine as shown here in operation on the 1 1/2" plates



The first cut was made at 90° to the plate surface as illustrated at left and above



The flame cut edges were beveled to 30° in the second operation on the plate as illustrated at left and below

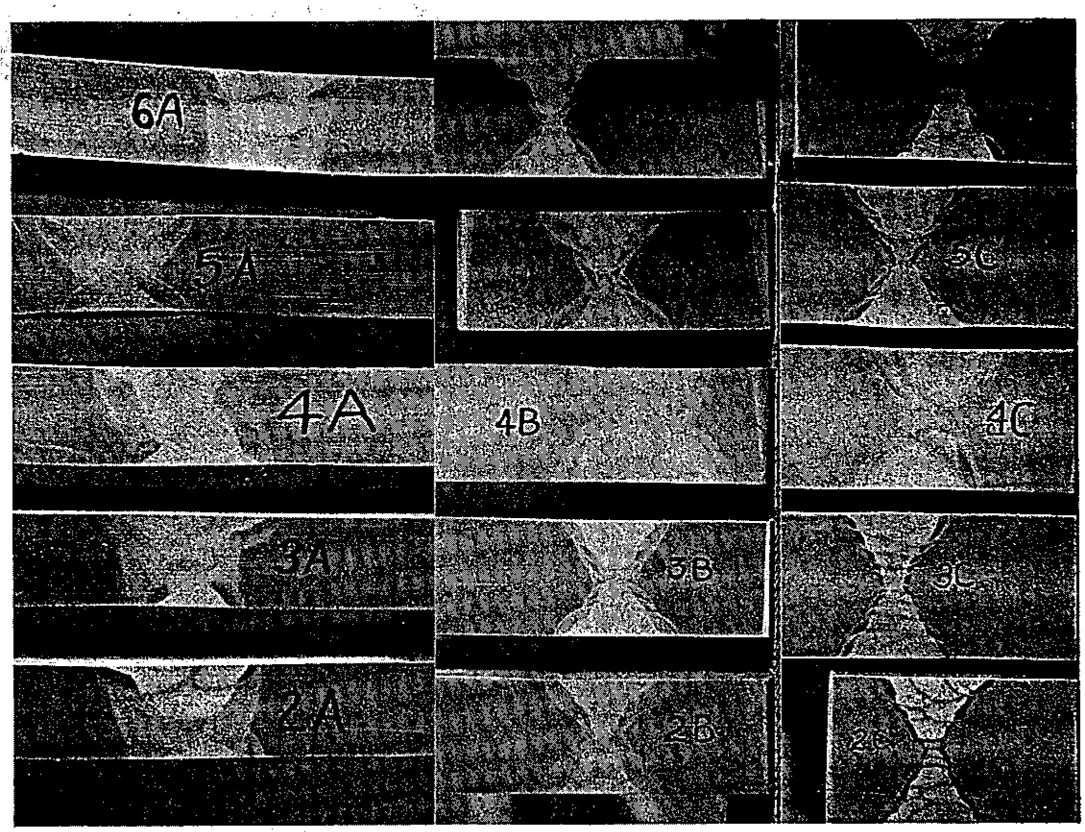


Front view of the Oxyacetylene beveling on the 1 1/2" thick test plate. Settings of oxygen pressure, speed of cutting, in inches per minute, and size of cutting tip were as recomended by the manufacturer for this cutting equipment

[illegible]

WELDING

Exhibit 27



1/2" plate 1" plate 1-1/2" plate

Welds listed by number from top to bottom are as follows.

6. Airco manual low hydrogen using 352 (E12015) electrodes.

5. Aircomatic semi-automatic inert gas shielded arc using a 98% argon – 2% oxygen shield with A632 electrode wire.

4. Unionmelt, automatic, submerged arc, using #80 flux with #866 electrode wire. (Oxweld wire)

3. Airco manual low hydrogen using 353 (E10016) electrodes.

2. A. O. Smith manual low hydrogen using SW 91 (E11016 tentative) electrodes.

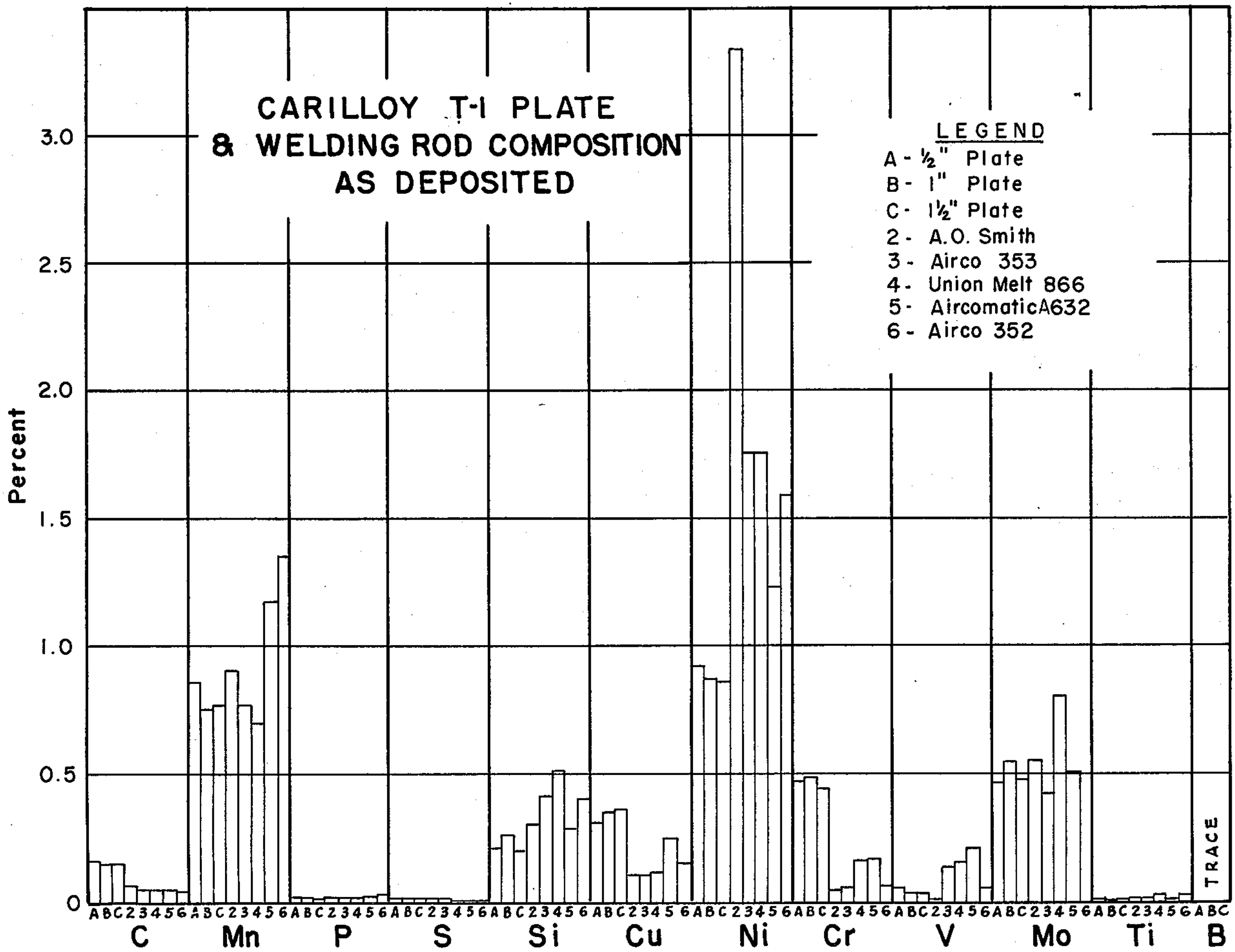
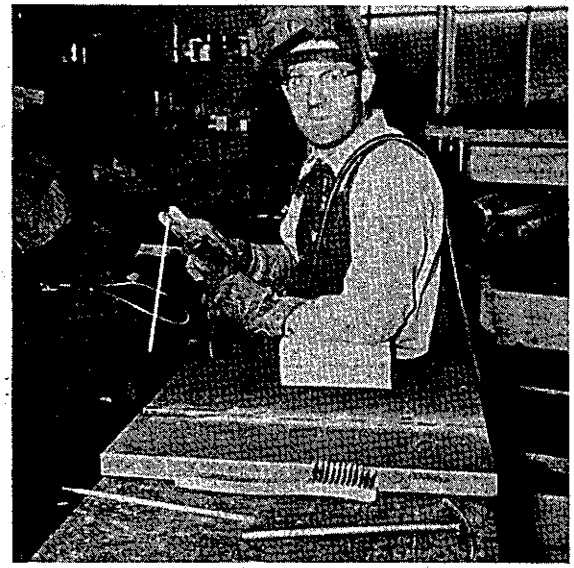


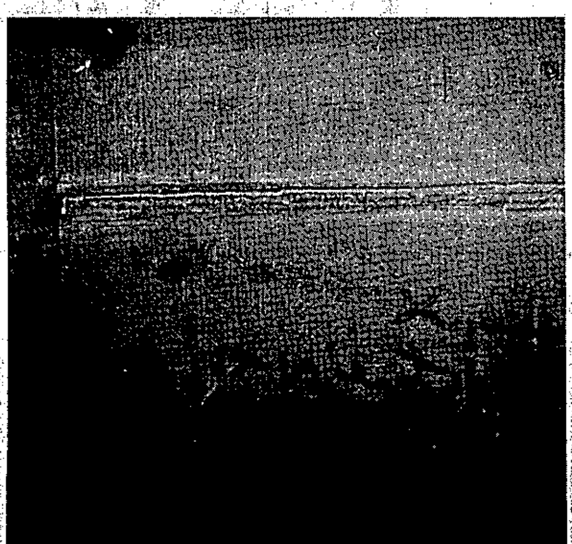
EXHIBIT NO. 28

MANUAL WELDING



The manual welds were prepared by a State certified journeyman welder using a downhand position as shown here.

Here can be seen the electrode tilt angle used in manually welding the 1 1/2" thick Carilloy T-1 test plate.



The finished weld test plate is seen here. The temperature from welding on the test plate was not allowed to exceed 400°F inter-pass temp.

MANUAL WELDING

DETAILS

OF

BUTT WELDED JOINTS

USING

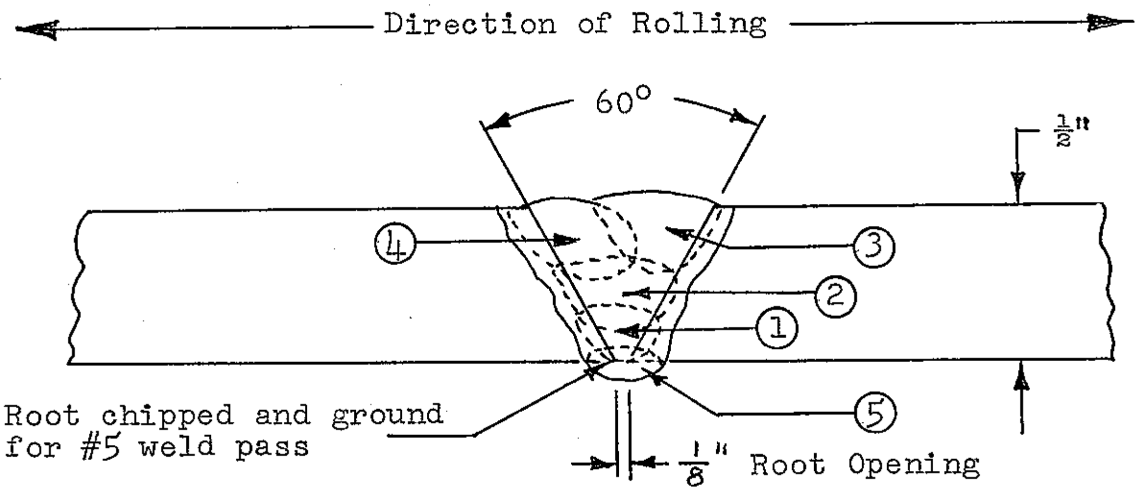
A. O. SMITH

S. W. 91, LOW HYDROGEN ELECTRODES

(E-11016 TENTATIVE)

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1

½" Steel Plate No. 2A



Type of Welding Process - Manual

No. of Passes - 5

Electrode - A. O. Smith No. SW-91 low hydrogen

Electrode Diameter 5/32" and 3/16"

Current - Direct

Polarity - Reverse

Amperes - 150 to 230

Arc-volts 25 ±

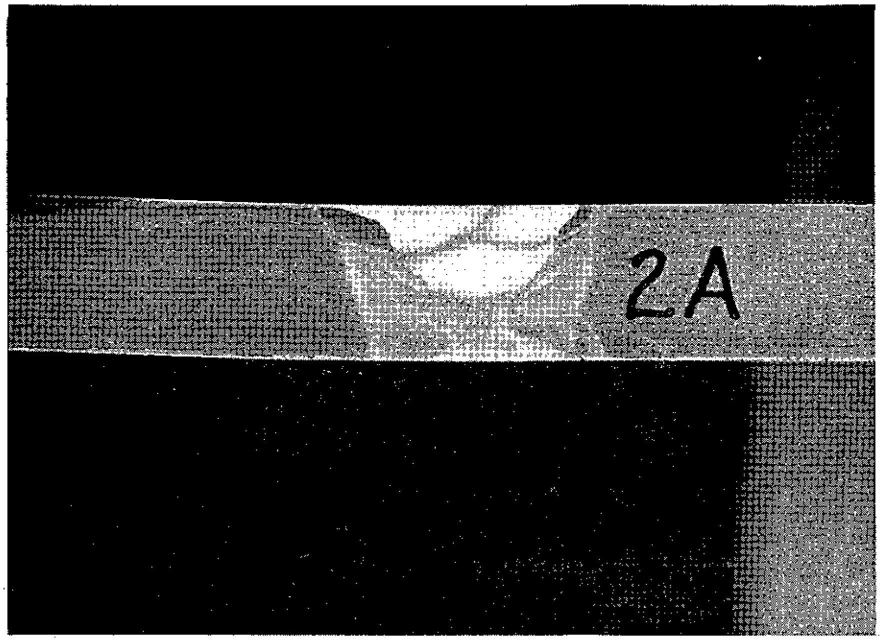
Average Welding Speed of Travel - 4½" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. Welding Area - 400°F

Normal Cool Down to Room Temp.

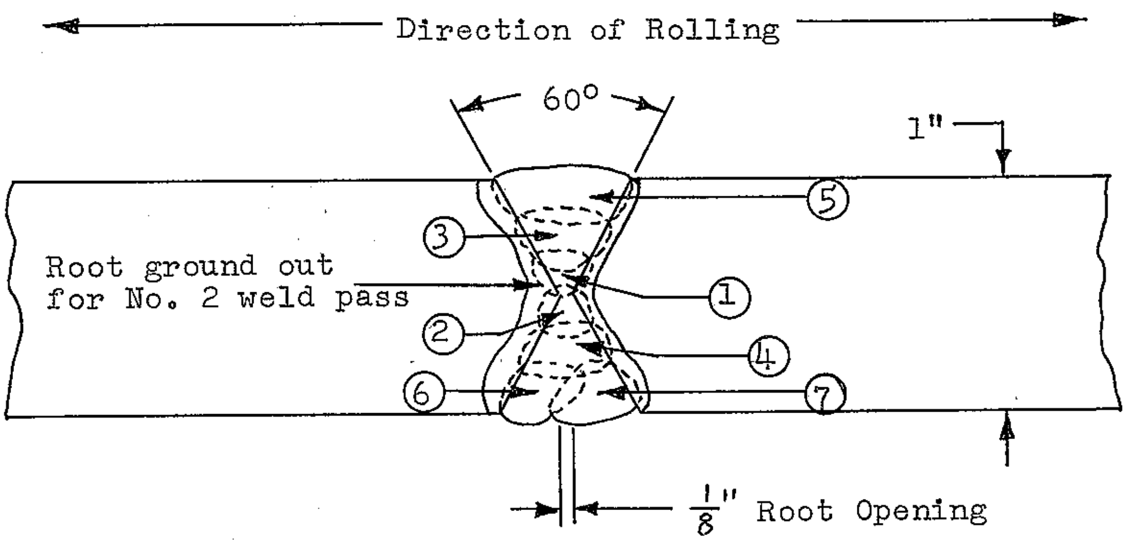
Note: Passes No. 1 and 5 were welded with 5/32" diameter electrode.



Cross section of 1/2" butt joint manually welded using A. O. Smith SW 91 (E-11016 tentative) electrodes.

DETAILS OF STANDARD BUTT WELD FOR CARILLOY T-1

1" Steel Plate No. 2B



Type of Welding Process - Manual

No. of Passes - 7

Electrode Type - A. O. Smith No. SW 91 low hydrogen

Electrode Diameter - 5/32" and 3/16"

Current - Direct

Polarity - Reverse

Amperes - 160 - 240

Arc-volts 25 ±

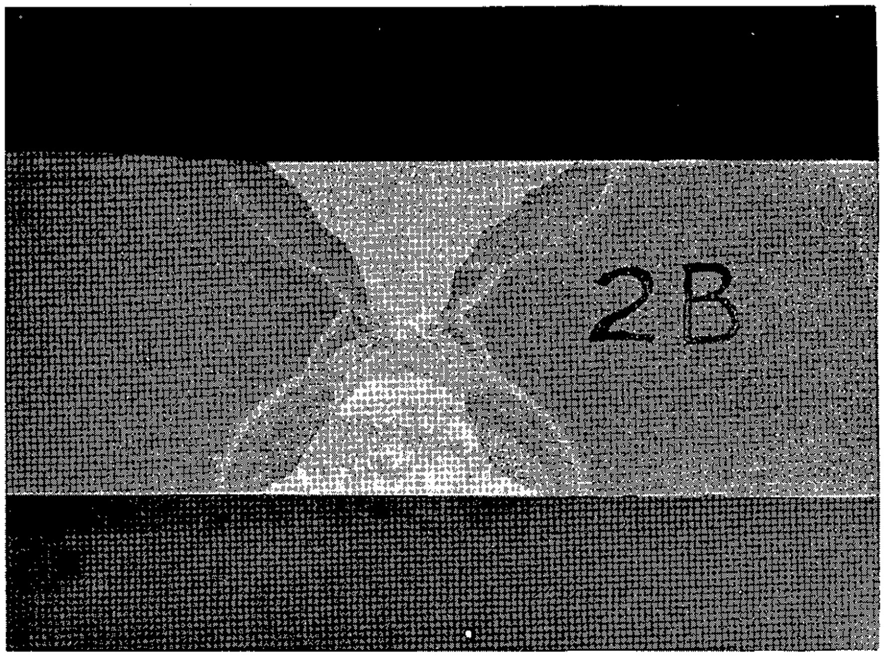
Average Welding Speed of Travel - 4" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. - Welding Area 400°F

Normal Cool Down to Room Temp.

Note: Weld passes No. 1 and 2 were welded with 5/32" diameter electrode.

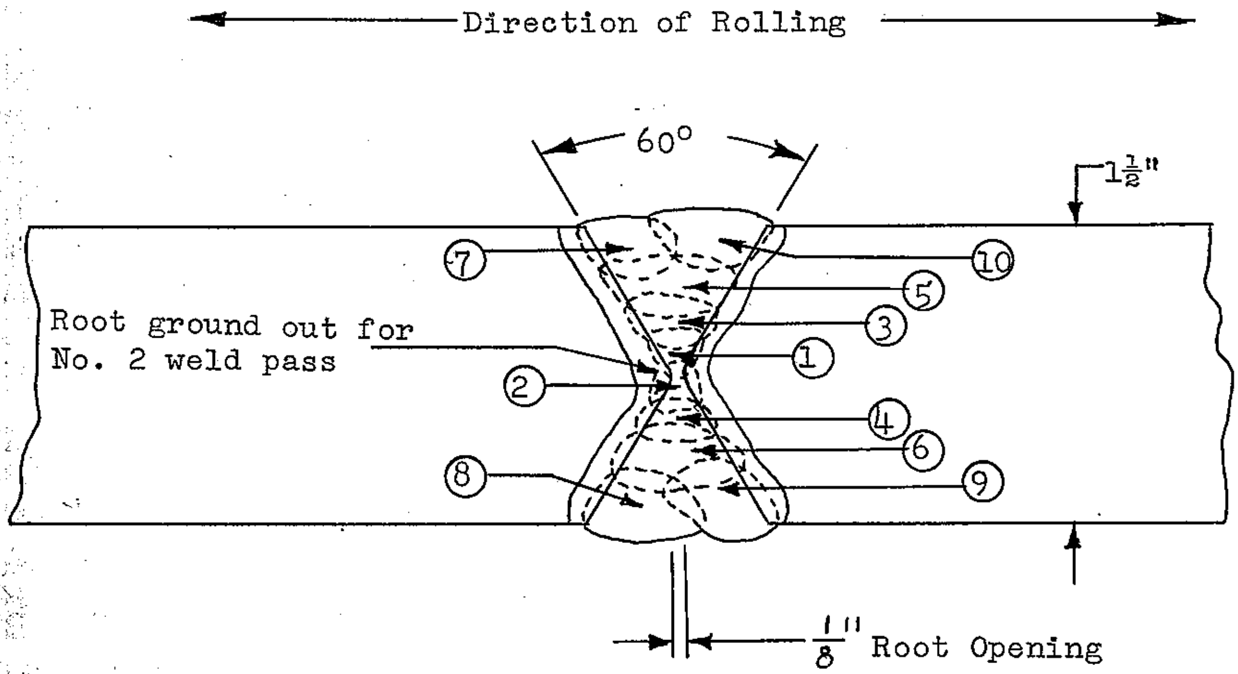


Cross-Section of 1" butt joint manually
welded using A. O. Smith SW 91 (E11016
tentative) electrodes.

Exhibit 34

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1

$1\frac{1}{2}$" Steel Plate No. 2C



Type of Welding Process - Manual

No. of Passes - 10

Electrode Type - A. O. Smith No. SW91 low hydrogen

Electrode Diameter - 5/32" and 3/16"

Current - Direct

Polarity - Reverse

Amperes - 160 - 240

Arc-volts 25 ±

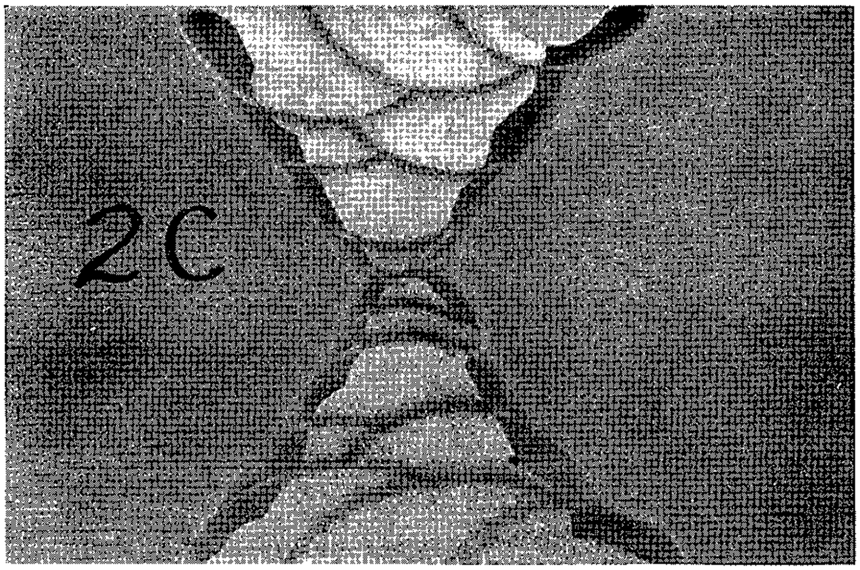
Average Welding Speed of Travel - $3\frac{1}{2}$" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. - Welding Area 400°F

Normal Cool Down to Room Temp.

Note: Weld passes No. 1 and 2 welded with 5/32" diameter electrodes.



Cross-section of 1 1/2" butt joint manually welded using A. O. Smith SW 91 (E11016 tentative) electrodes.

MANUAL WELDING

DETAILS

OF

BUTT WELDED JOINTS

USING

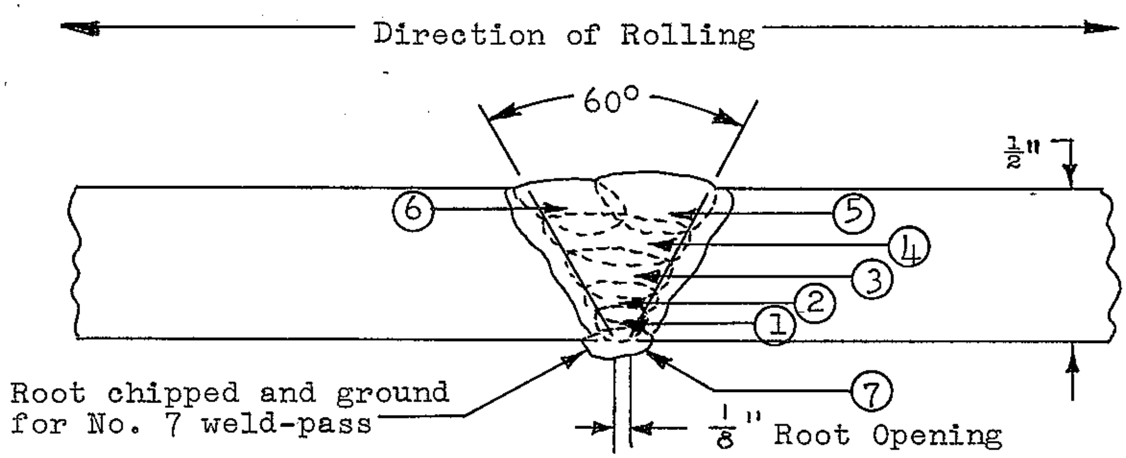
AIRCO

353, LOW HYDROGEN ELECTRODES

(E-10016)

DETAIL OF STANDARD BUTT WELD FOR CARILLOY T-1

$\frac{1}{2}$" Steel Plate No. 3A



Type of Welding Process - Manual

No. of Passes - 7

Electrode - Airco No. 353-E10016 low hydrogen

Electrode Diameter - 5/32"

Current - Direct

Polarity - Reverse

Amperes - 140 to 160

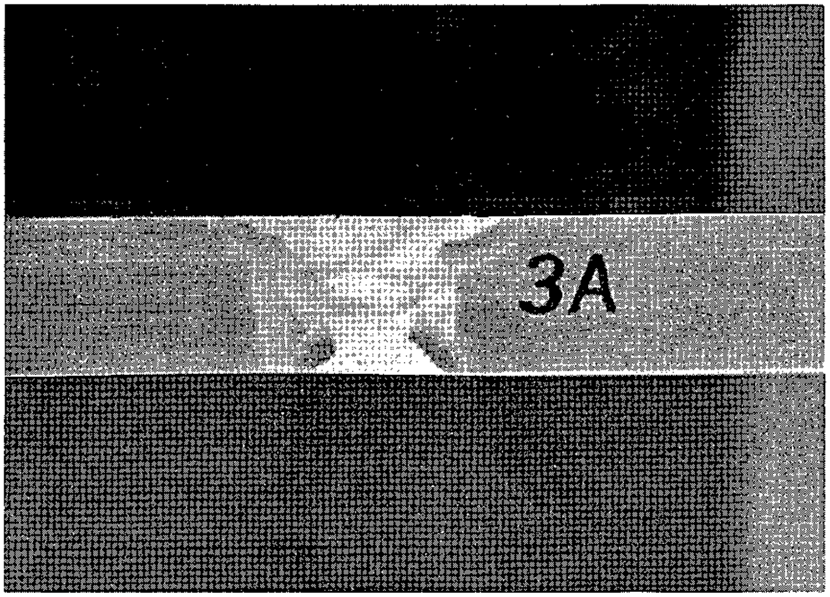
Arc-volts 24 $\pm$

Average Welding Speed of Travel - 5" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. - Welding Area 400°F

Normal Cool Down to Room Temp.

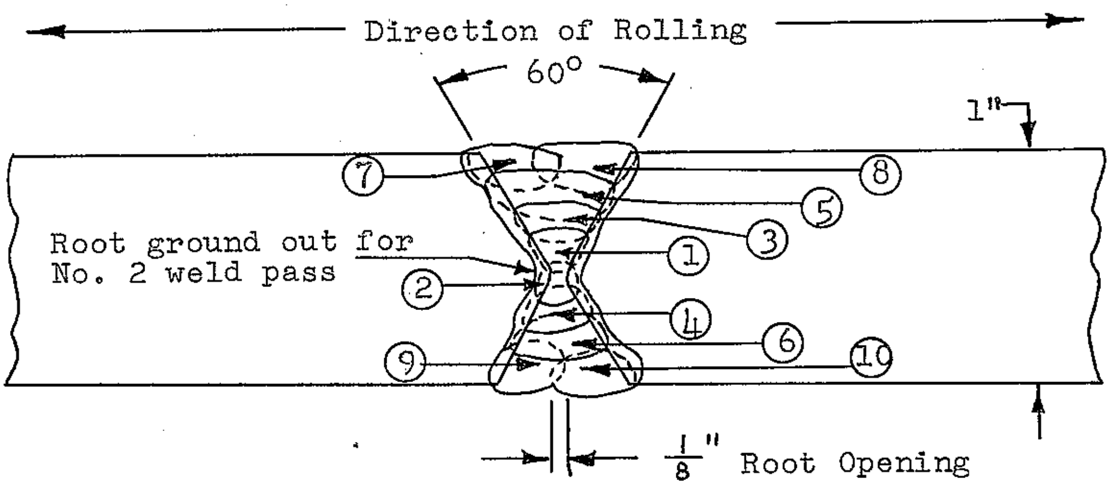


Cross-section of 1/2" butt joint manually welded using Airco 353 E-10016 electrodes.

Exhibit 38

DETAILS OF STANDARD BUTT WELD FOR CARILLOY T-1

1" Steel Plate No. 3B



Type of Welding Process - Manual

No. of Passes - 10

Electrode Type - Airco 353 - E10016 low hydrogen

Electrode Diameter - 5/32"

Current - Direct

Polarity - Reverse

Amperes - 150 to 170

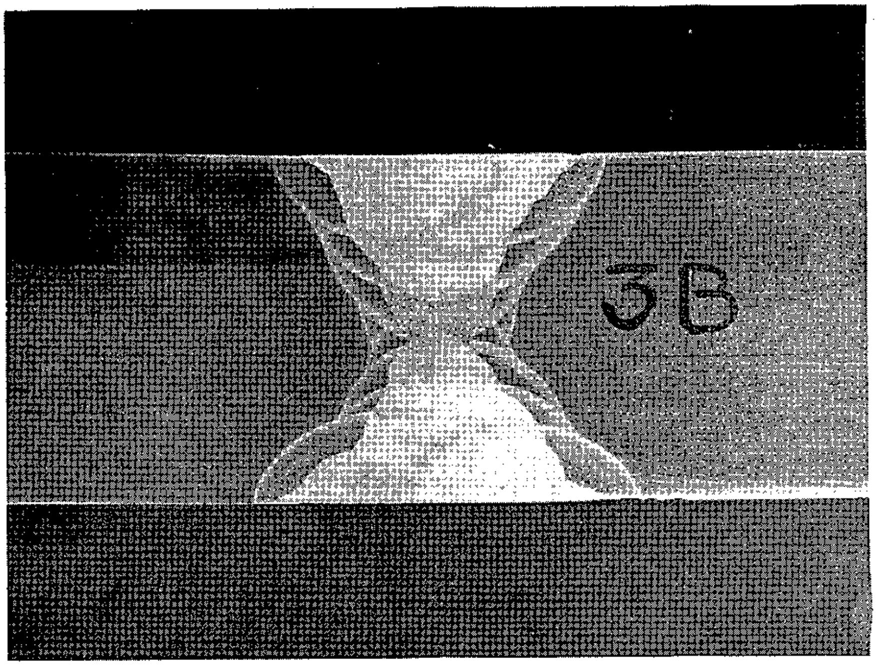
Arc-volts 20 ±

Average Welding Speed of Travel - 5" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.

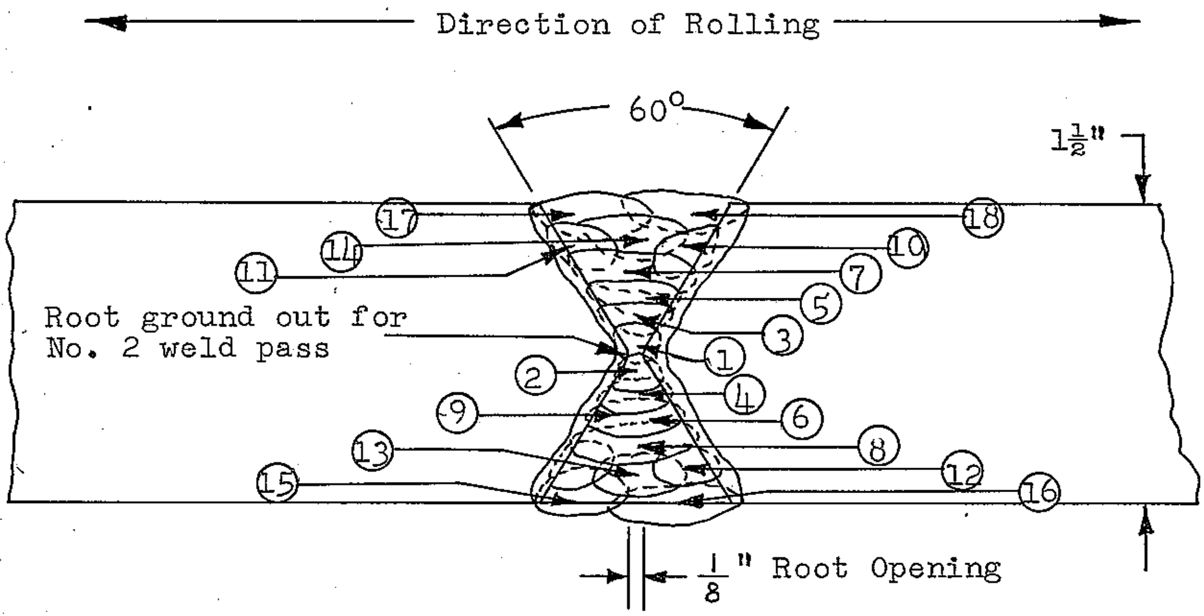


Cross-section of 1" butt joint manually welded using Airco 353 E-10016 electrodes.

Exhibit 40

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1

$1\frac{1}{2}$" Steel Plate No. 3C



Type of Welding Process - Manual

No. of Passes - 18

Electrode Type - Airco 353 E10016 low hydrogen

Electrode Diameter - 5/32"

Current - Direct

Polarity - Reverse

Amperes - 160 to 170

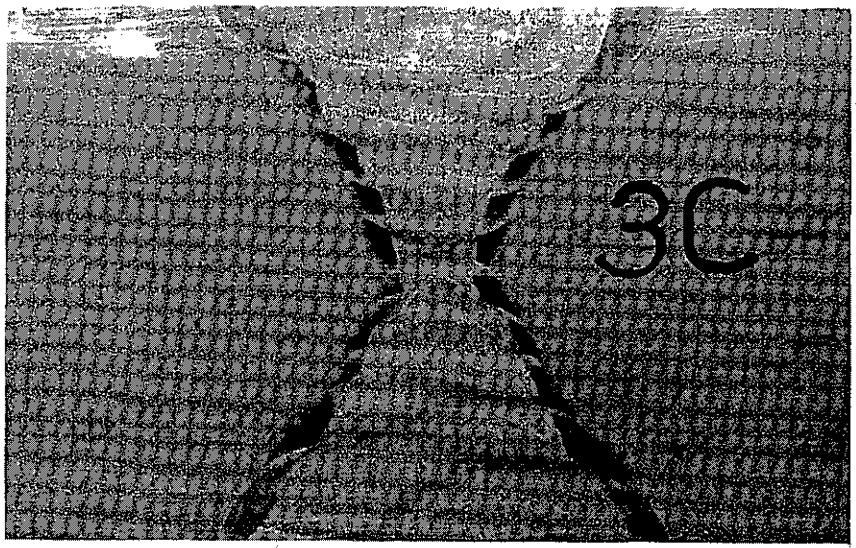
Arc-volts 20±

Average Welding Speed of Travel - 4" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 350°F

Normal Cool Down to Room Temp.



Cross-section of 1 1/2" butt joint manually welded using Airco 353 E-10016 electrodes.

MANUAL WELDING

DETAILS

OF

BUTT WELDED JOINTS

USING

AIRCO

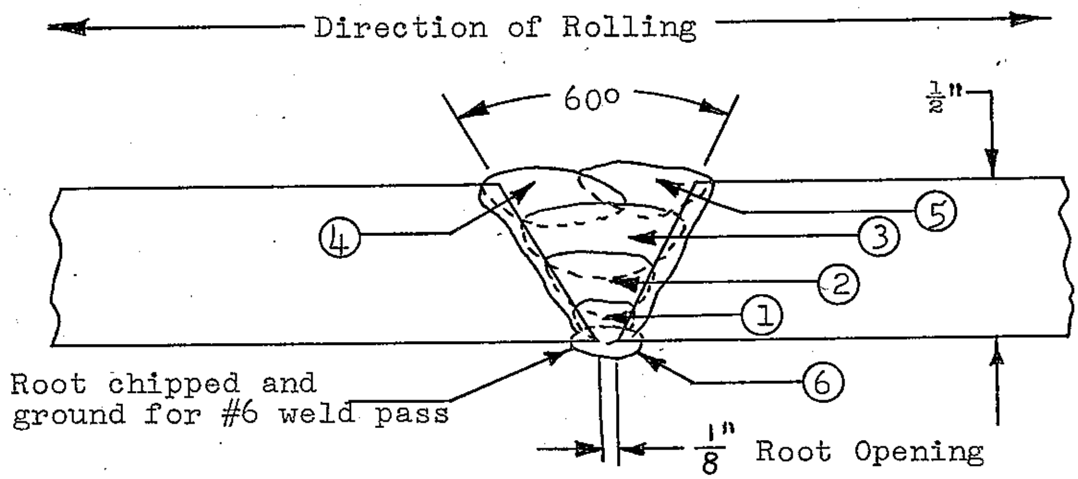
352, LOW HYDROGEN ELECTRODES

(E-12015)

Exhibit 42

DETAILS OF STANDARD BUTT-WELD FOR THE CARILLOY T-1

$\frac{1}{2}$" Steel Plate No. 6A



Type of Welding Process - Manual

No. of Passes - 6

Electrode Type - Airco #352 - E12015 low hydrogen

Electrode Diameter 5/32"

Current - Direct

Polarity - Reverse

Amperes - 140 to 160

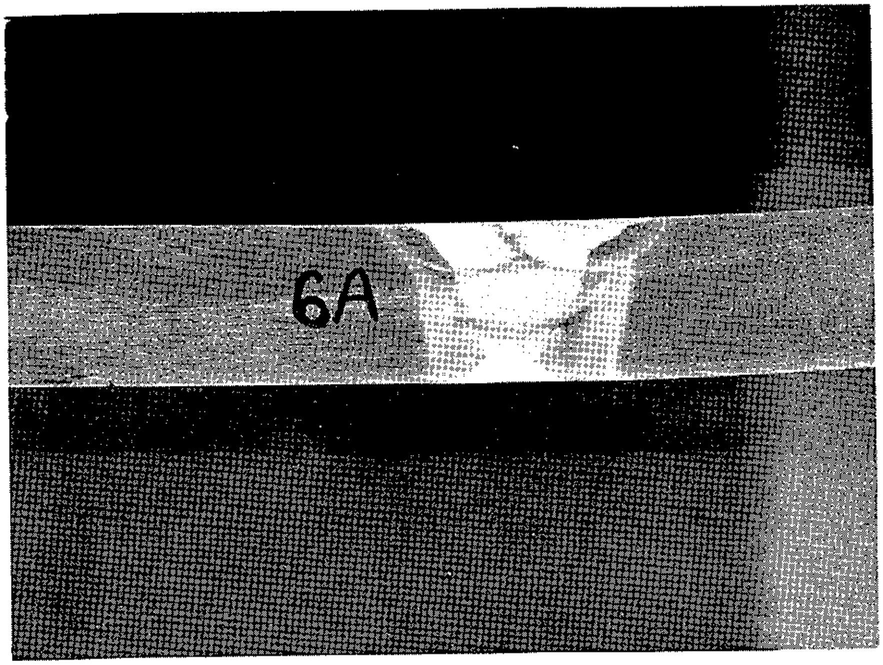
Arc-volts 24 ±

Average Welding Speed of Travel - 5" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. - Welding Area - 400°F

Normal Cool Down to Room Temp.

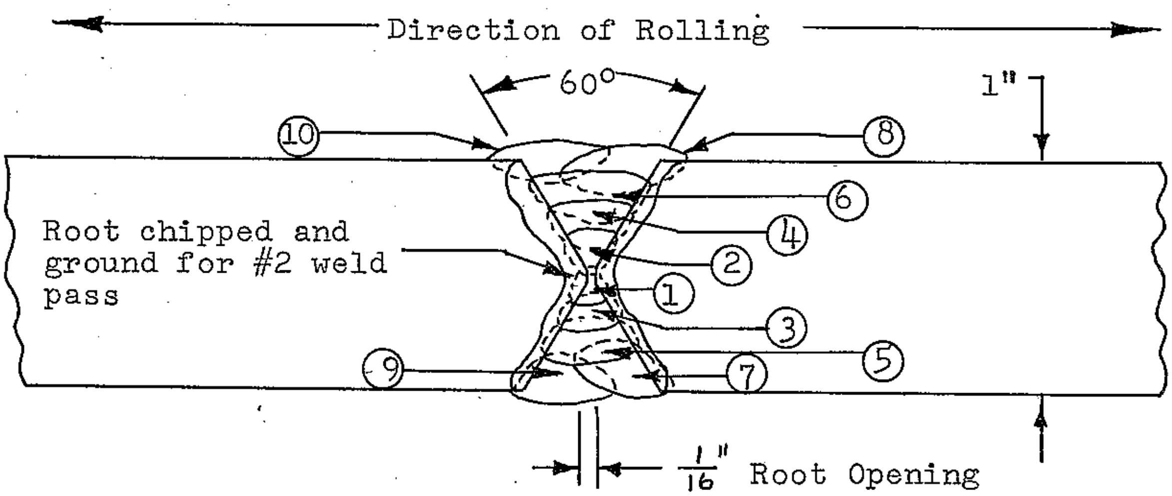


Cross-section of 1/2" butt joint manually welded using Airco 352 E-12015 electrodes.

Exhibit 44

DETAILS OF STANDARD BUTT WELD FOR CARILLOY T-1

1" Steel Plate No. 6B



Type of Welding Process - Manual

No. of Passes - 10

Electrode Type - Airco #352 - E12015 low hydrogen

Electrode Diameter - 5/32" and 3/16"

Current - Direct

Polarity - Reverse

Amperes - 160 to 220

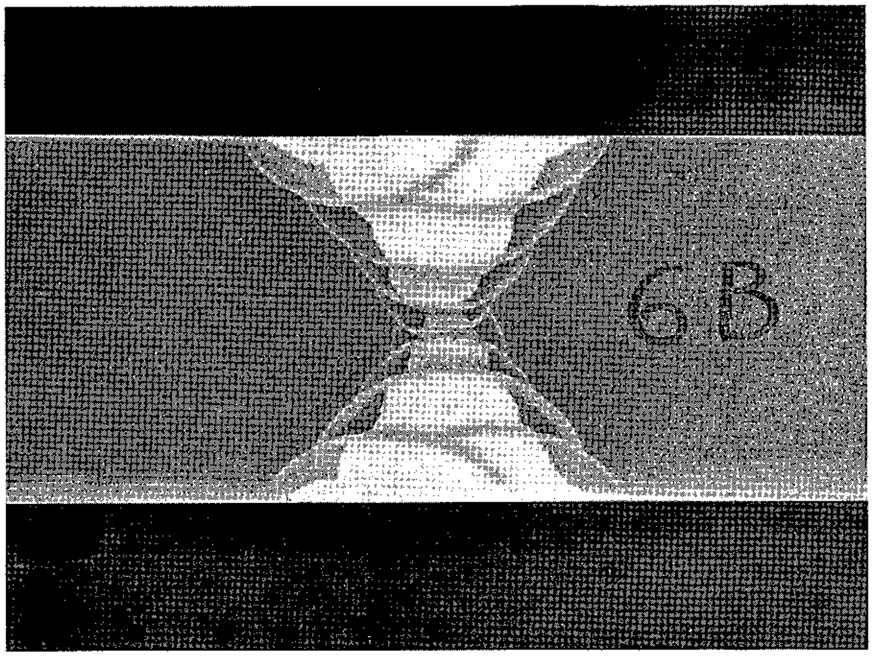
Arc-volts 24 ±

Average Welding Speed of Travel 5" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.

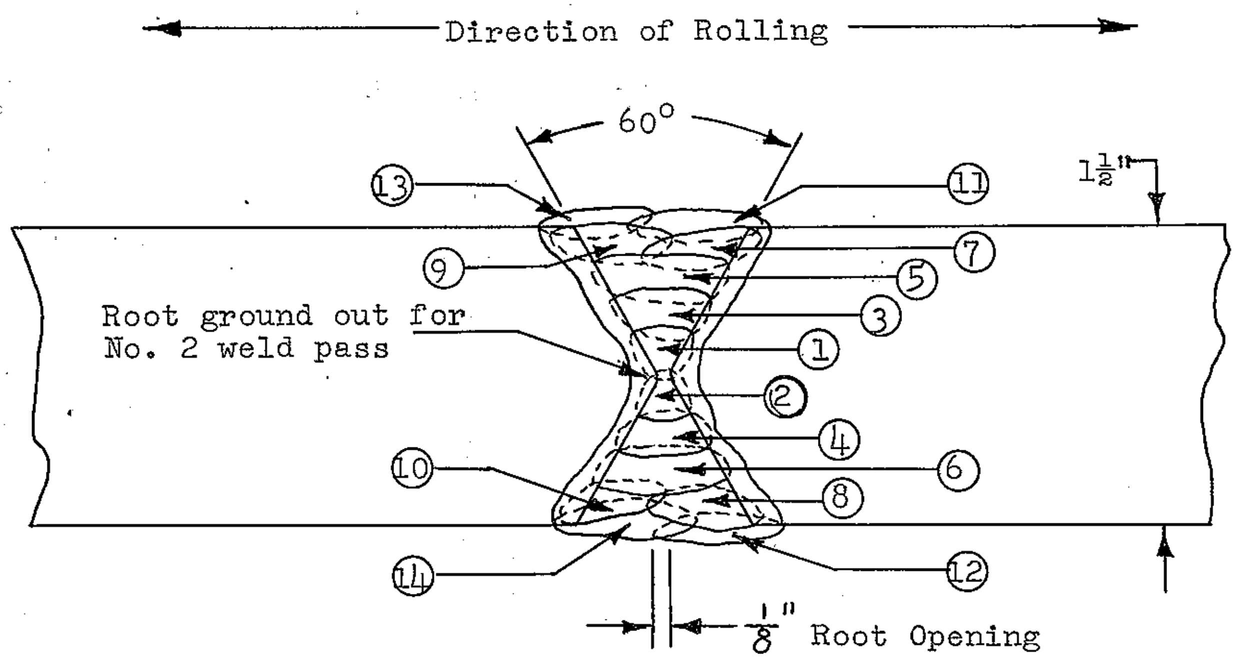


Cross-section of 1" butt joint manually welded using Airco 352 E-12015 electrodes.

Exhibit 46

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1

$1\frac{1}{2}$" Steel Plate No. 6C



Type of Welding Process - Manual

No. of Passes - 14

Electrode Type - Airco No. 352 - E12015 - low hydrogen

Electrode Diameter - 5/32" and 3/16"

Current - Direct

Polarity - Reverse

Amperes - 150 to 220

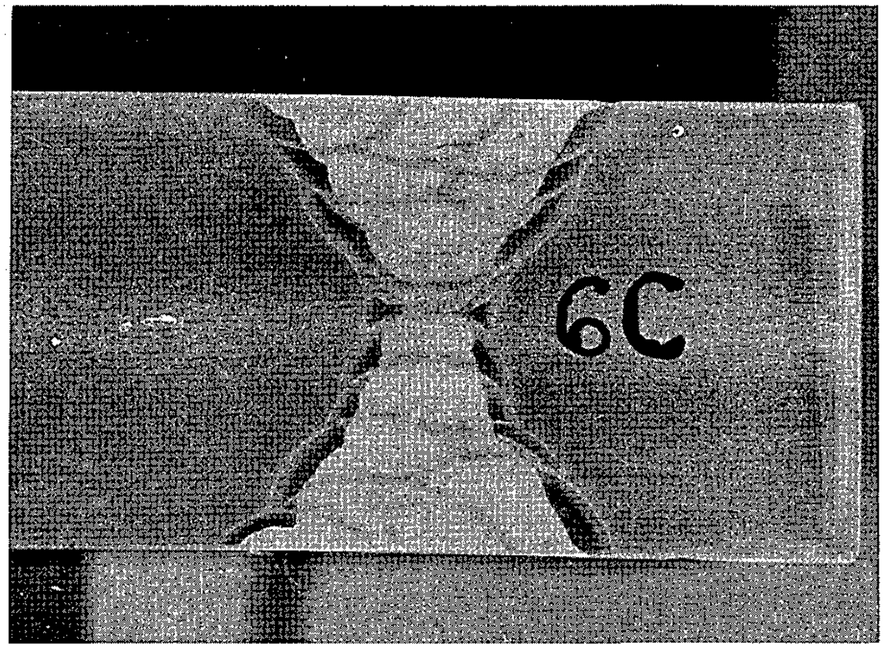
Arc-volts 24 $\pm$

Average Welding Speed of Travel 5" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.



Cross-section of 1 1/2" butt joint manually welded using Airco 352 E-12015 electrodes.

AUTOMATIC WELDING

DETAILS

OF

BUTT WELDED JOINTS

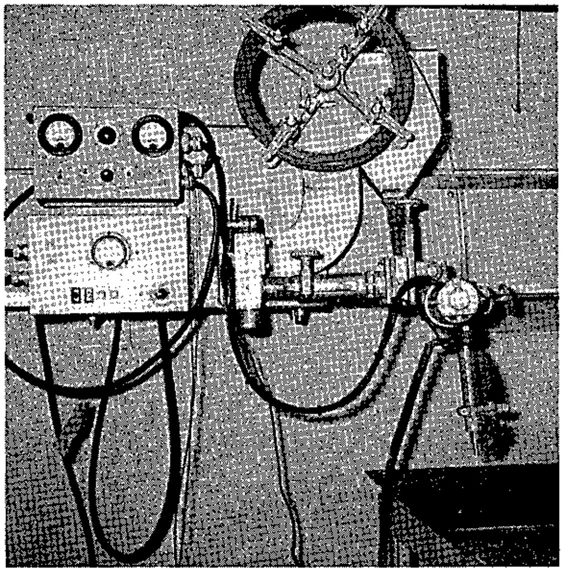
USING

UNIONMELT SUBMERGED ARC PROCESS

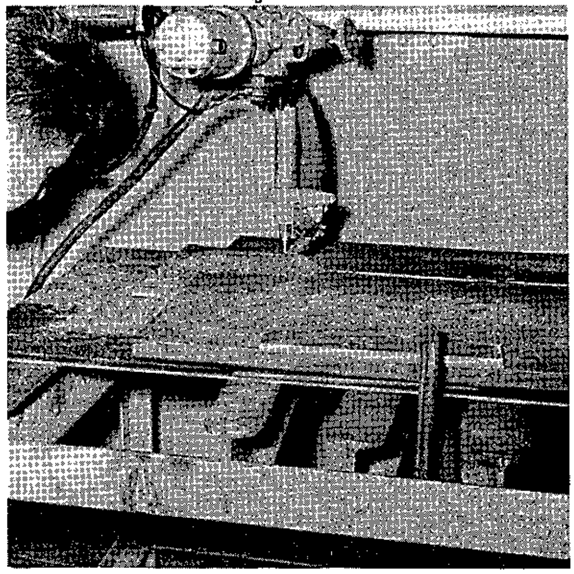
WITH

OXWELD 866 ELECTRODE WIRE AND 80 FLUX

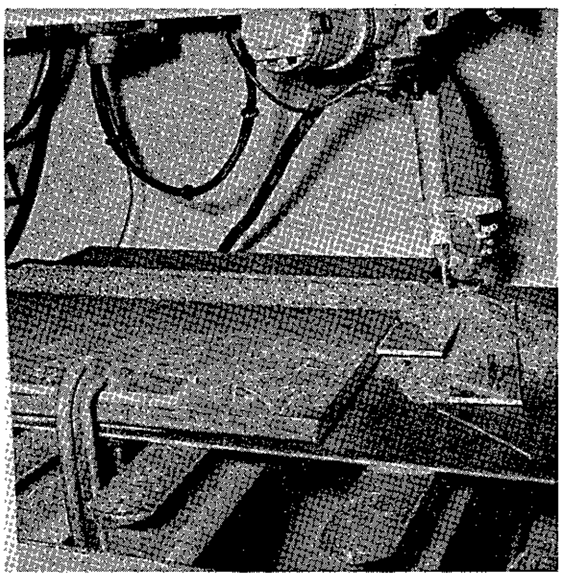
UNIONMELT SUBMERGED-ARC AUTOMATIC WELDING EQUIPMENT



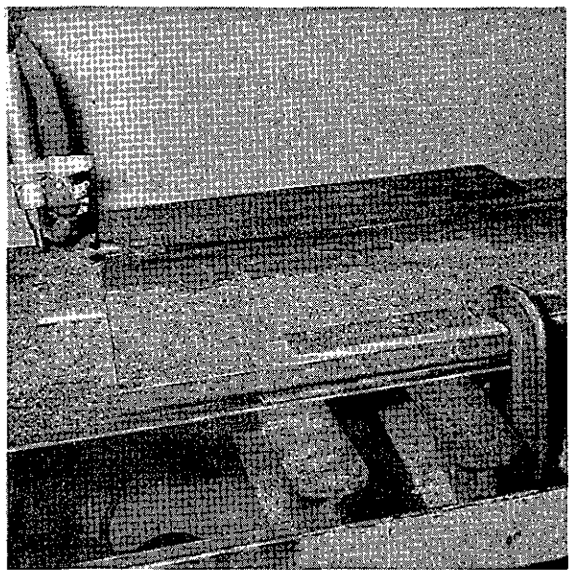
Seen above are the current regulator, the wire feed, and the flux bin.



Note the flux feed covering the arc during the pass.



The Completed Pass

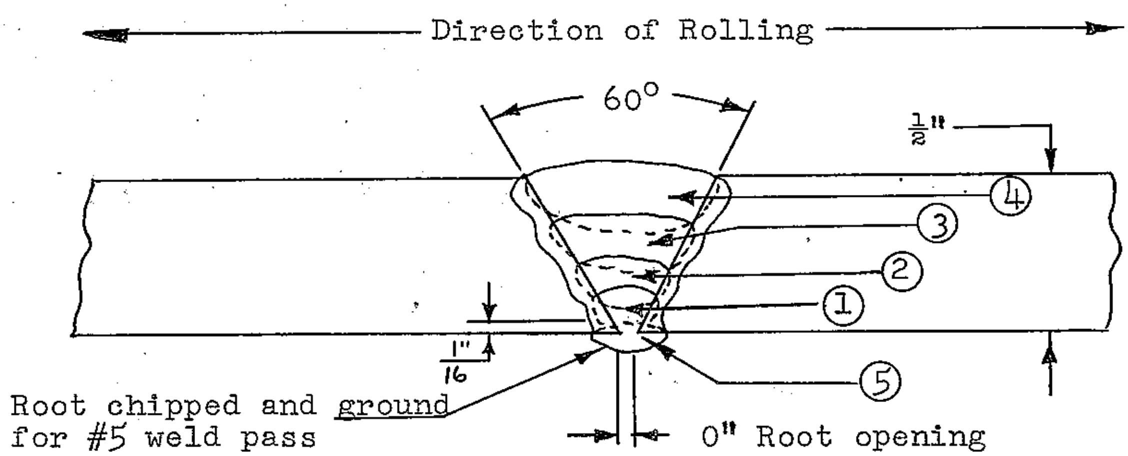


Note the flux peeling off the weld

Exhibit 49

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1

$\frac{1}{2}$" Steel Plate No. 4A



Type of Welding Process - Submerged Arc - Linde Air - Unionmelt

No. of Passes - 5

Flux - Composition Grade No. 80 - 12 x 65 - Unionmelt

Electrode Type - 866 Oxweld

Electrode Diameter - 1/8"

Current - Direct

Polarity - Reverse

Amperes - 350 to 450

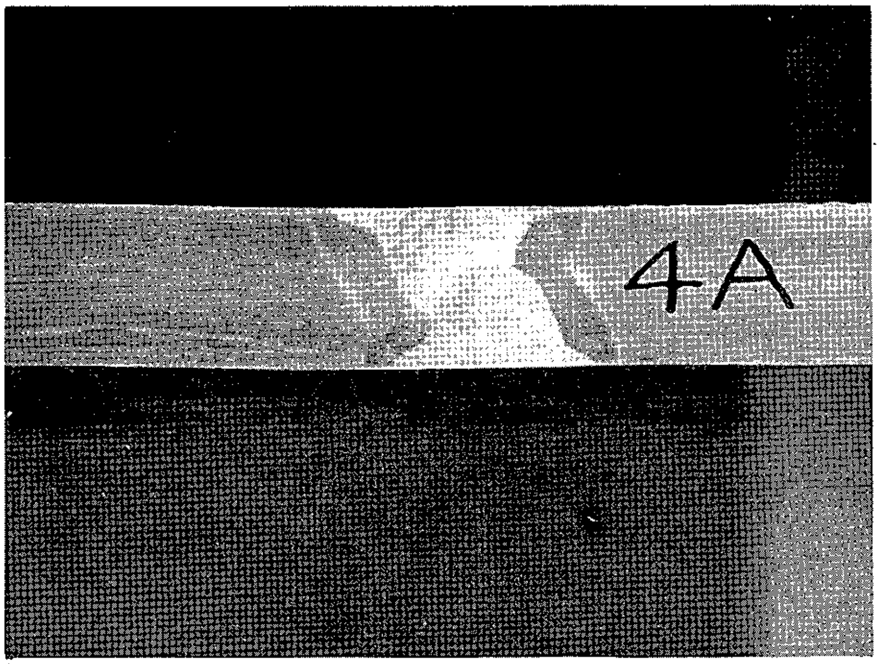
Arc-Volts 28$\pm$ 2 to 30 $\pm$ 2 volts

Average Welding Speed of Travel 14" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. - Welding Area - 400°F

Normal Cool Down to Room Temp.



Cross-section of 1/2" butt joint automatically welded using the Unionmelt submerged-arc process.

Welding pass detail for the weld as follows:

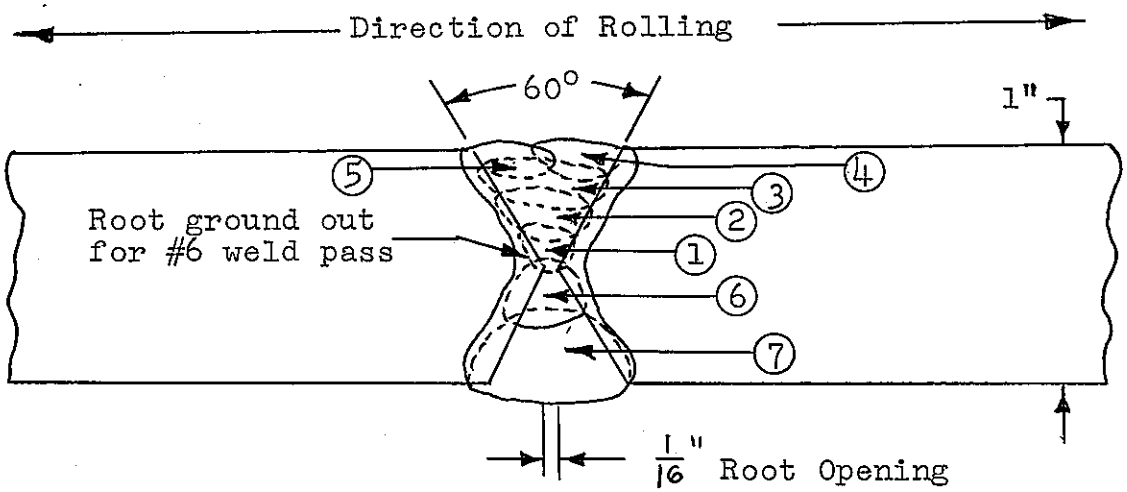
Pass	In/Min	Volts	Amps
1	22	28	350
2	18	30	350
3	14	30	350
4	14	30	450
*5	14	30	450

*Note: The No. 5 pass was welded after back-grinding down to the #1 pass with a disc sander in order to insure complete penetration.

Exhibit 51

DETAILS OF STANDARD BUTT WELD FOR CARILLOY T-1

1" Steel Plate No. 4B



Type of Welding Process - Submerged Arc - Linde Air, Unionmelt

No. of Passes - 7

Flux Composition - Grade 80 - 12 x 65 - Unionmelt

Electrode Type - 866 Oxweld

Electrode Diameter - 1/8"

Current - Direct

Polarity - Reverse

Amperes - 450 to 550

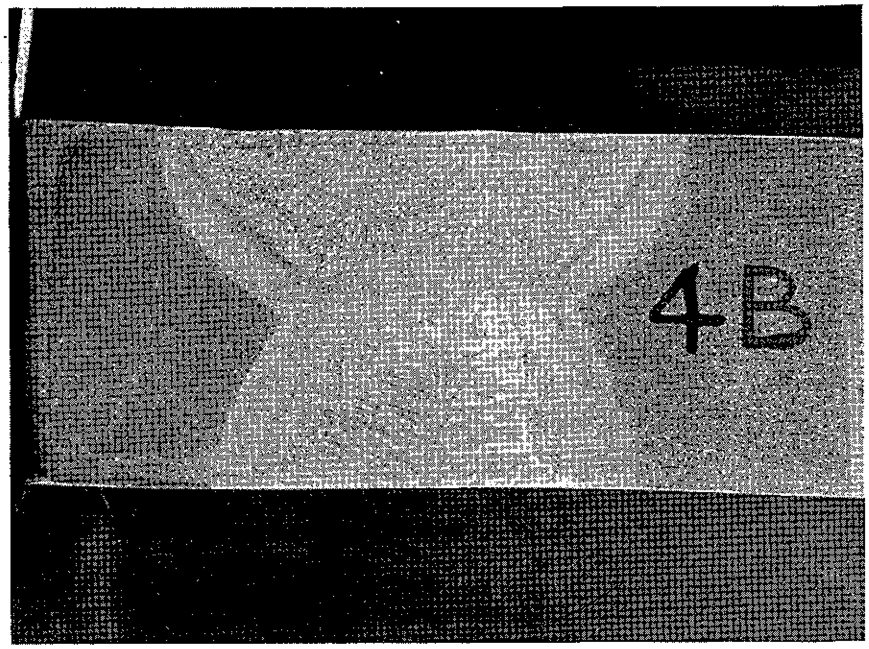
Arc-volts 30 ± 2 volts

Average Welding Speed of Travel - 12" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.



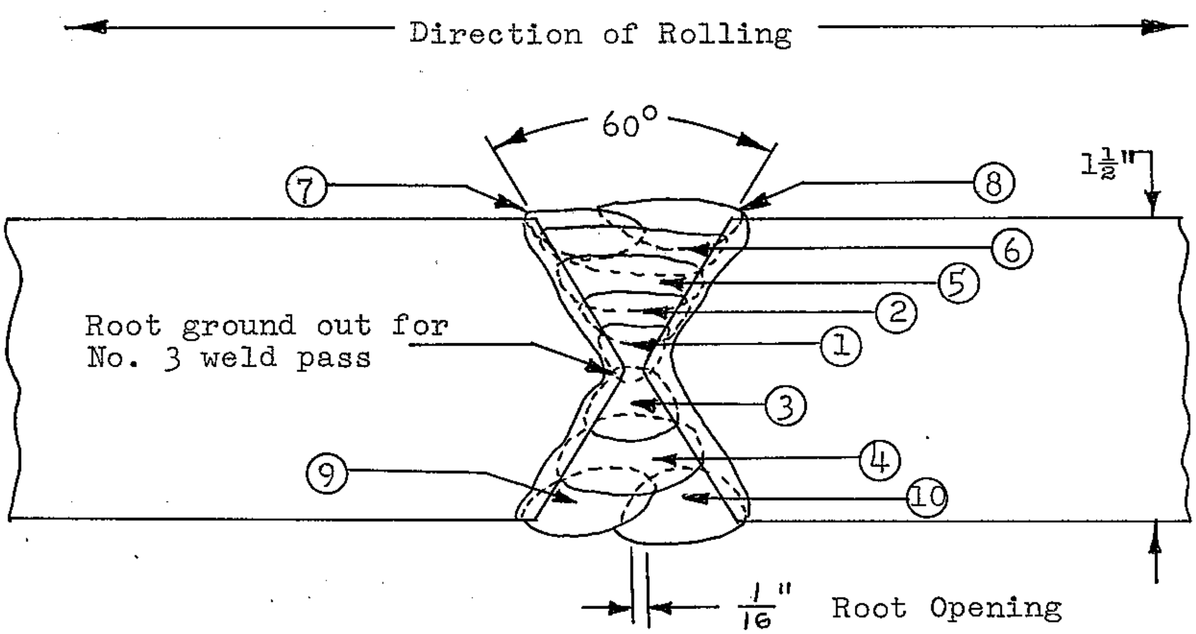
Cross-section of 1" butt joint automatically welded using the Unionmelt submerged-arc process.

Welding pass detail for the weld as follows:

Pass	In/Min	Volts	Amps
1	22	29/31	450
2	18	29/31	500
3	14	29/30	550
4	12	29/30	550
5	12	29/30	550
6	10	29/31	550
7	10	29/31	550

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1

$1\frac{1}{2}$" Steel Plate No. 4C



Type of Welding Process - Submerged arc - Linde Air - Unionmelt

No. of Passes - 10

Flux - Composition - Grade 80 - 12 x 65 Unionmelt

Electrode Type - 866 Oxweld

Electrode Diameter - 1/8"

Current - Direct

Polarity - Reverse

Amperes - 430 to 550

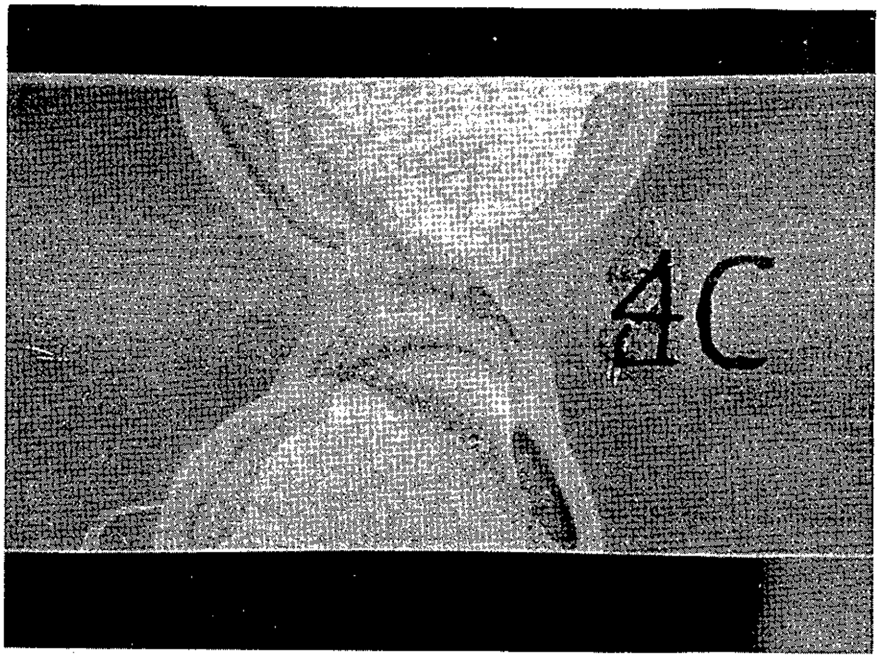
Arc-volts 30 $\pm$ 2 volts

Average Welding Speed of Travel - 10" and 14" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.



Cross-section of 1 1/2" butt joint automatically welded using the Unionmelt submerged-arc process

Welding pass detail for the weld as follows:

Pass	In/Min	Volts	Amps
1	18	29/30	430
2	14	29/30	430
3	14	29/30	500
4	10	29/30	550
5	10	29/30	550
6	10	29/30	550
7	10	29/30	550
8	10	29/30	550
9	10	29/30	550
10	10	29/30	550

SEMI-AUTOMATIC WELDING

DETAILS

OF

BUTT WELDED JOINTS

USING

AIRCOMATIC INERT GAS SHIELDED ARC PROCESS

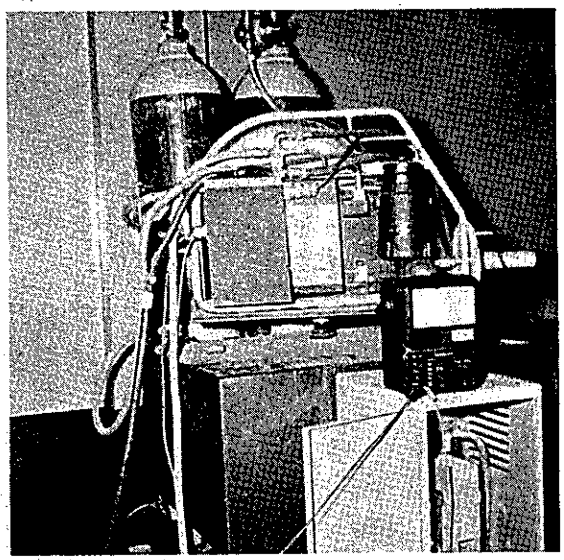
WITH

A632 ELECTRODE WIRE AND A 98%A - 2%O_2 SHIELD

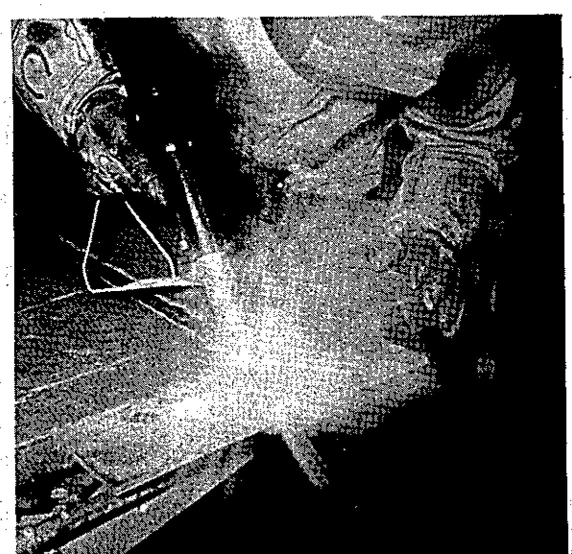
Exhibit 55

AIRCOMATIC INERT GAS SHIELDED ARC SEMI-AUTOMATIC WELDING EQUIPMENT

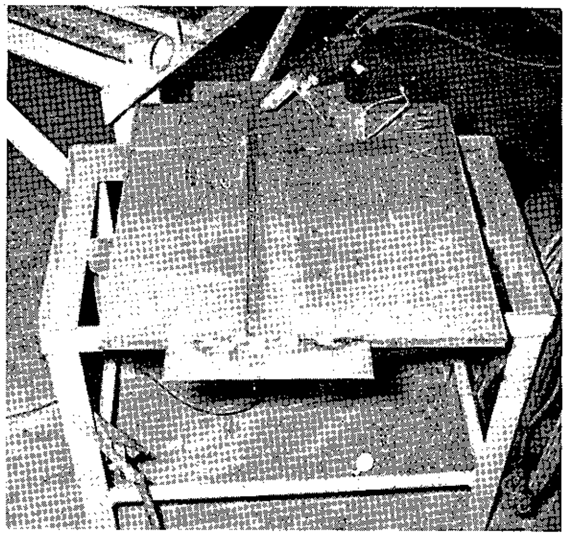
The power supply, Airco D.C. Bumblebee, used for the Aircomatic welding process. The test plates No. 5A-5B-5C.



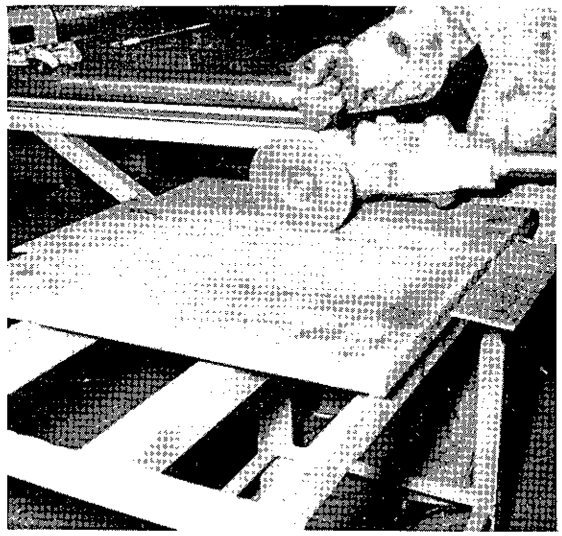
Gas and wire feed control unit for the Aircomatic welding process.



This is the manual operating position for the type 21 Aircomatic gun used semi-automatically.

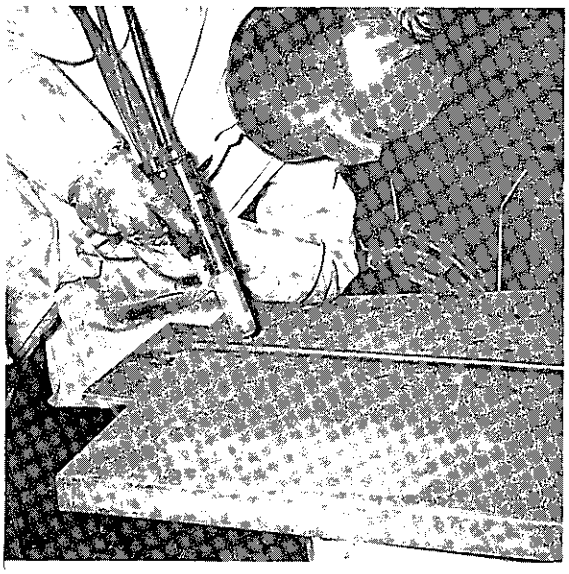


The first weld pass here put in with manually operated Aircomatic welding on the 1" thick test plate 5B.



A disc sander was used to grind down the first weld pass to insure complete penetration of the 2nd weld pass, on the side opposite the 1st weld pass.

Illustrating the angle of operation used with the Aircomatic process.



The finished Aircomatic weld on test plate 5C.

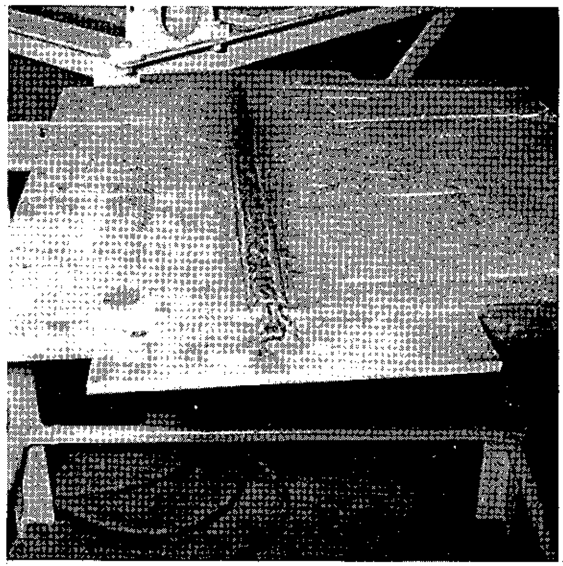
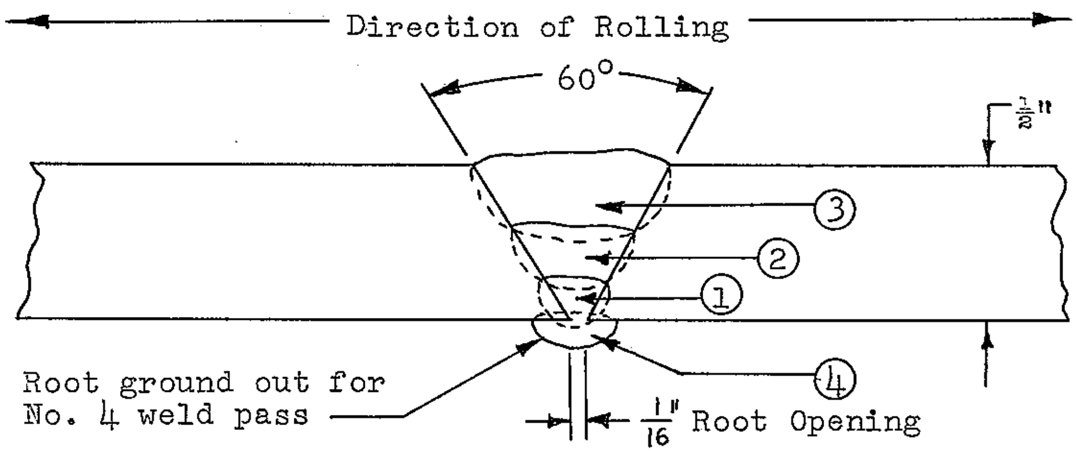


Exhibit 57

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1

$\frac{1}{2}$" Steel Plate No. 5A



Type of Welding Process - Aircomatic No. 21 Gun Gas Shield

No. of Passes - 4

Electrode Type - A632 - Alloy No. 2

Gas Flow - Low Side 30/CFH

Gas Shield - Argon (No. 2) 98% Argon (2% O_2)

Electrode Diameter - 1/16"

Electrode Wire Feed 240 inches per min.

Current - Direct

Polarity - Reverse

Amperes - 360

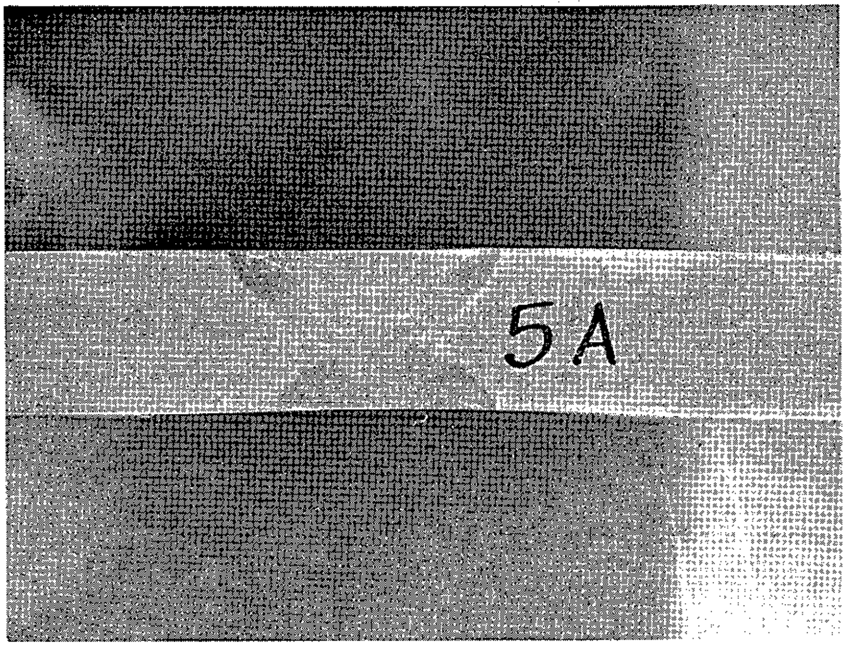
Arc-volts 30 $\pm$ 2 volts

Average Welding Speed of Travel 12 and 16" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. - Welding Area 400°F

Normal Cool Down to Room Temp.



Cross-section of 1/2" butt joint semi-auto matically welded using the Aircomatic inert gas shielded arc process with A632 electrode wire.

Welding pass detail for the welds are as follows:

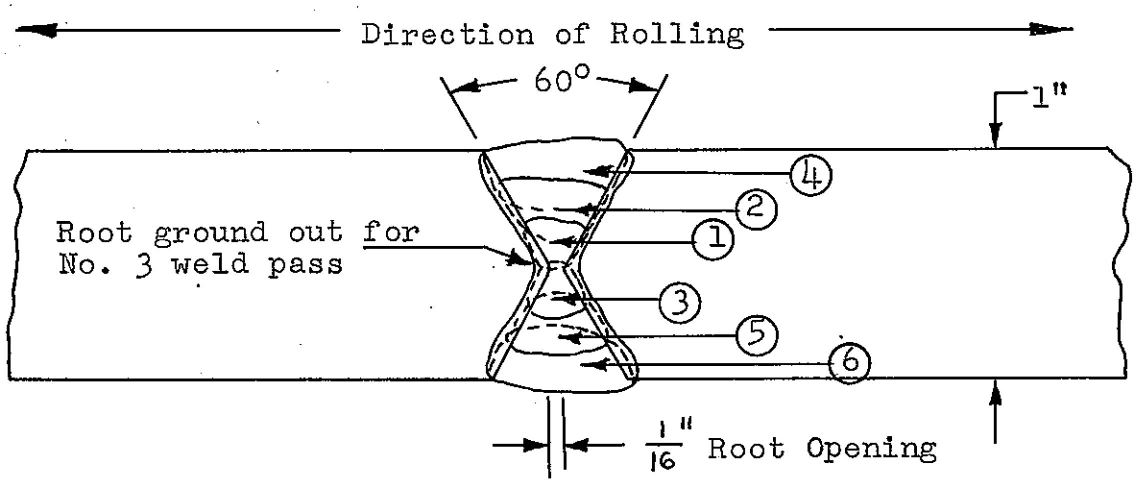
Pass no.	Amps.	Volts	wire feed per/min	Gas Flow	Inches Per Min
1	360	30/31	240	30/CFH	20
2	360	30/31	240	30/CFH	16
3	360	31/33	240	30/CFH	12
4	360	31/32	240	30/CFH	16

The no. 4 pass was welded after back grinding down to the No. 1 weld pass with a disc sander in order to insure complete penetration.

Exhibit 59

DETAILS OF STANDARD BUTT WELD FOR CARILLOY T-1

1" Steel Plate No. 5B



Type of Welding Process - Aircomatic: No. 21 gun, Gas Shield

No. of Passes - 6

Electrode Type - A632 Alloy No. 2

Electrode Diameter 1/16"

Gas Shield - Argon (No. 2) - 98% Argon (2% O_2)

Gas Flow - Low Side - 30/CFH

Current - Direct

Polarity - Reverse

Amperes - 365

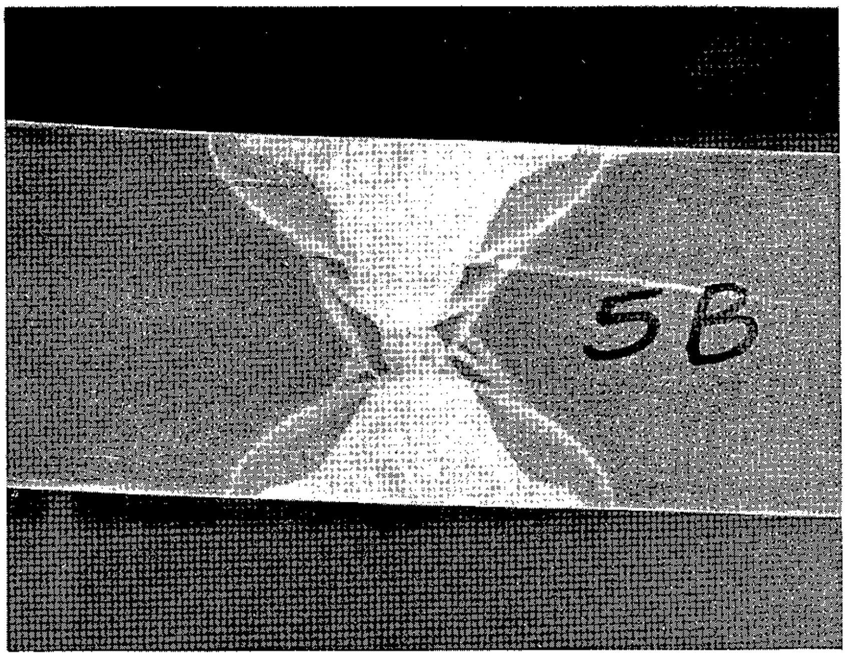
Arc-volts 30 ± 2 volts

Average Welding Speed of Travel - 12" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.



Cross-section of a 1" butt joint semi-automatically welded using the Aircomatic inert gas shielded arc process with A632 electrode wire.

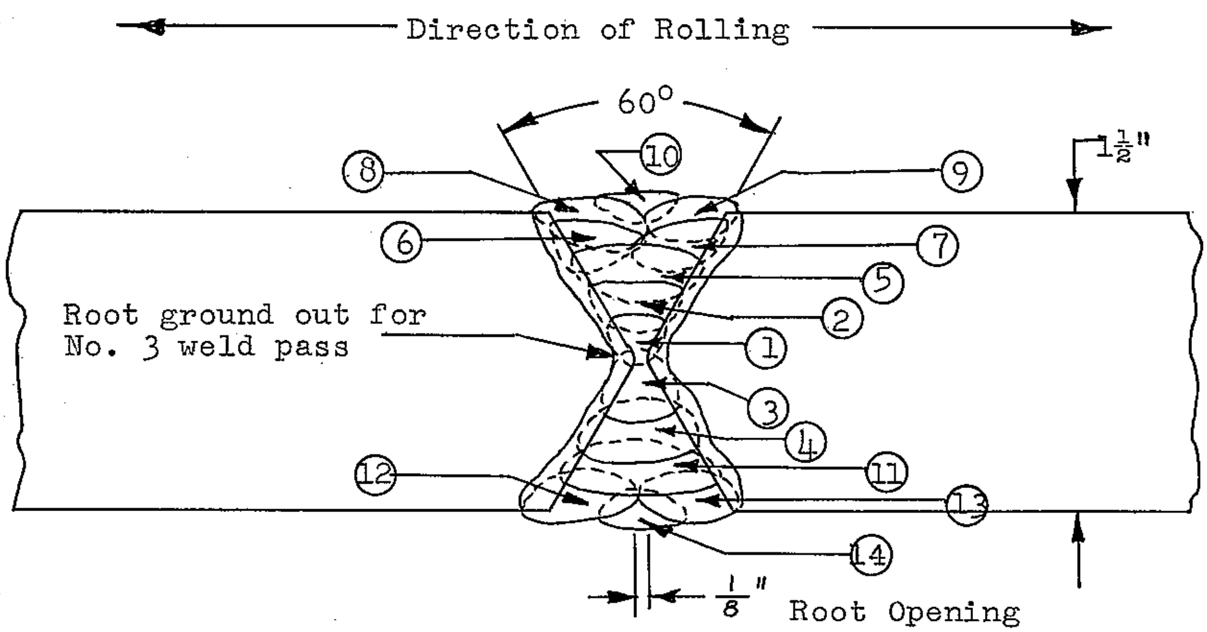
Welding pass detail for the welds are as follows:

Pass No.	Amp.	Volts.	Wire feed Per/min	Gas Flow Low Side	Welding Speed In/per minute
1	365	31/32	240"	30/CFH	16"
2	365	31/32	240"	30/CFH	14"
3	365	30/31	240"	30/CFH	13"
4	365	31/32	240"	30/CFH	9 1/2"
5	365	30/31	240"	30/CFH	12"
6	365	31/32	240"	30/CFH	8"

Exhibit 61

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1

$1\frac{1}{2}$" Steel Plate No. 5C



Type of Welding Process - Aircomatic No. 21 Gun, Gas Shield

No. of Passes - 14

Electrode Type - A632, Alloy No. 2

Electrode Diameter - 1/16"

Gas Shield - Argon (No. 2) - 98% Argon (2% O)

Gas Flow - Low Side 30/CFH

Current - Direct

Polarity - Reverse

Amperes - 160 to 365

Arc-volts - 30 $\pm$ 2 volts

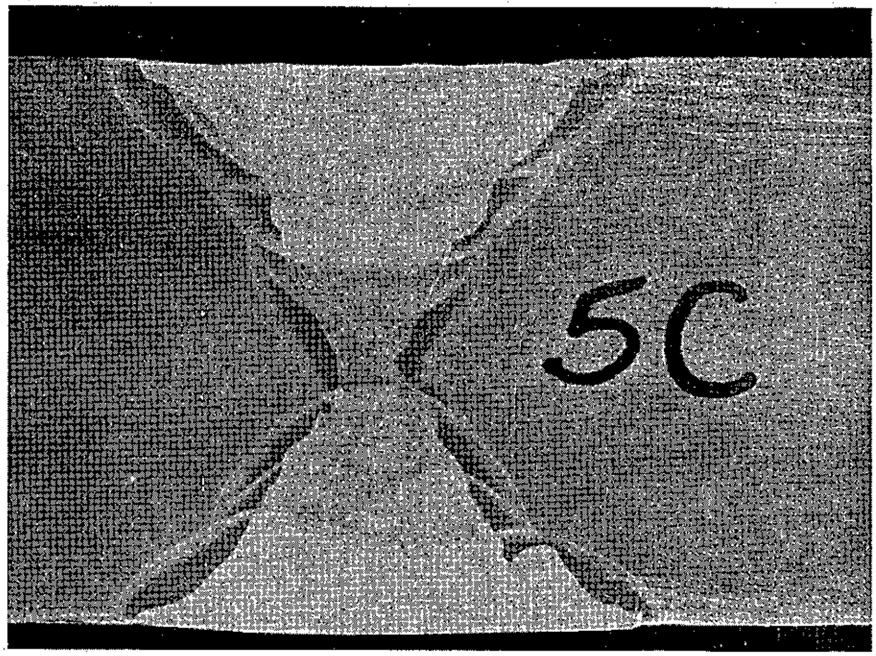
Average Welding Speed of Travel - 5", 10", 11", 14", 16" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.

Note: No. 1 weld pass was put in with 3/16" Airco 394 - low hydrogen electrode.



Cross-section of 1 1/2" butt joint semi-automatically welded using the Aircomatic inert gas shielded arc process with A632 electrode wire.

Welding pass detail for the welds are as follows:

Pass no.	Amps	Volts	wire feed per/min	gas flow low side	welding speed inches/per min
*1	160				5
2	365	31/32	240"	30/CFH	10.5"
3	365	31/32	240"	30/CFH	11"
4	365	31/32	240"	30/CFH	11"
5	365	31/32	240"	30/CFH	7.5"
6	365	31/32	240"	30/CFH	14"
7	365	31/32	240"	30/CFH	14"
8	365	31/32	240"	30/CFH	16"
9	365	31/32	240"	30/CFH	16"
10	365	31/32	240"	30/CFH	16"
11	365	31/32	240"	30/CFH	16"
12	365	31/32	240"	30/CFH	18"
13	365	31/32	240"	30/CFH	18"
14	365	31/32	240"	30/CFH	18"

*The #1 weld pass was welded manually with low hydrogen 3/16" electrode-Airco #394 E-10016.

VIII APPENDIX

SECTION D

SUMMARY OF TENSILE PROPERTIES

OF

TRANSVERSE BUTT WELDS

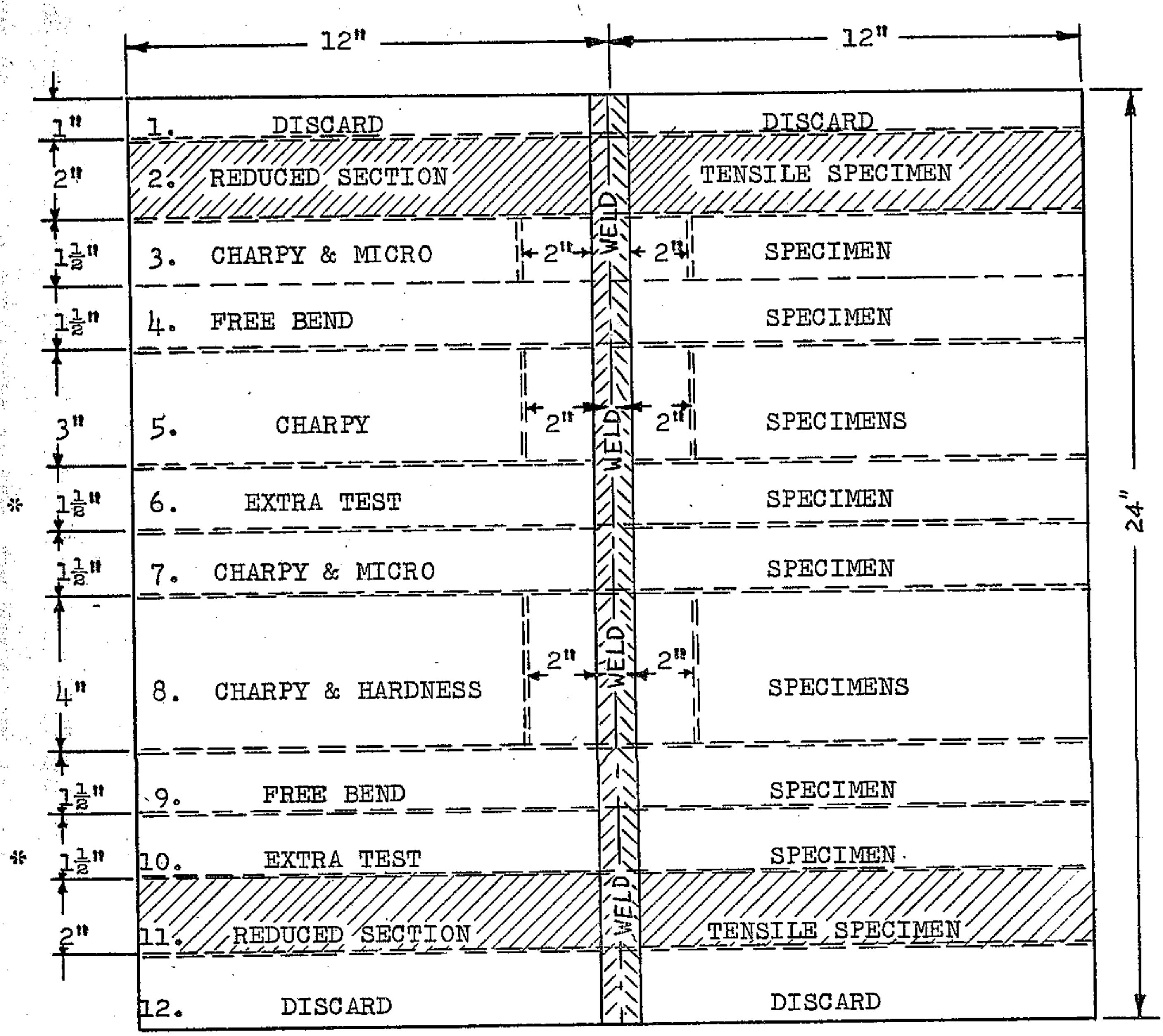
WITH

PHOTOGRAPHS

Exhibit 63

PLAN FOLLOWED IN CUTTING SPECIMENS

From $\frac{1}{2}$" CARILLOY T-1 STEEL TEST PLATES



* Extra Test Specimens for Proof Testing.

PLAN FOLLOWED IN CUTTING SPECIMENS

From 1" and $1\frac{1}{2}$" Carilloy T-1 Steel Test Plates

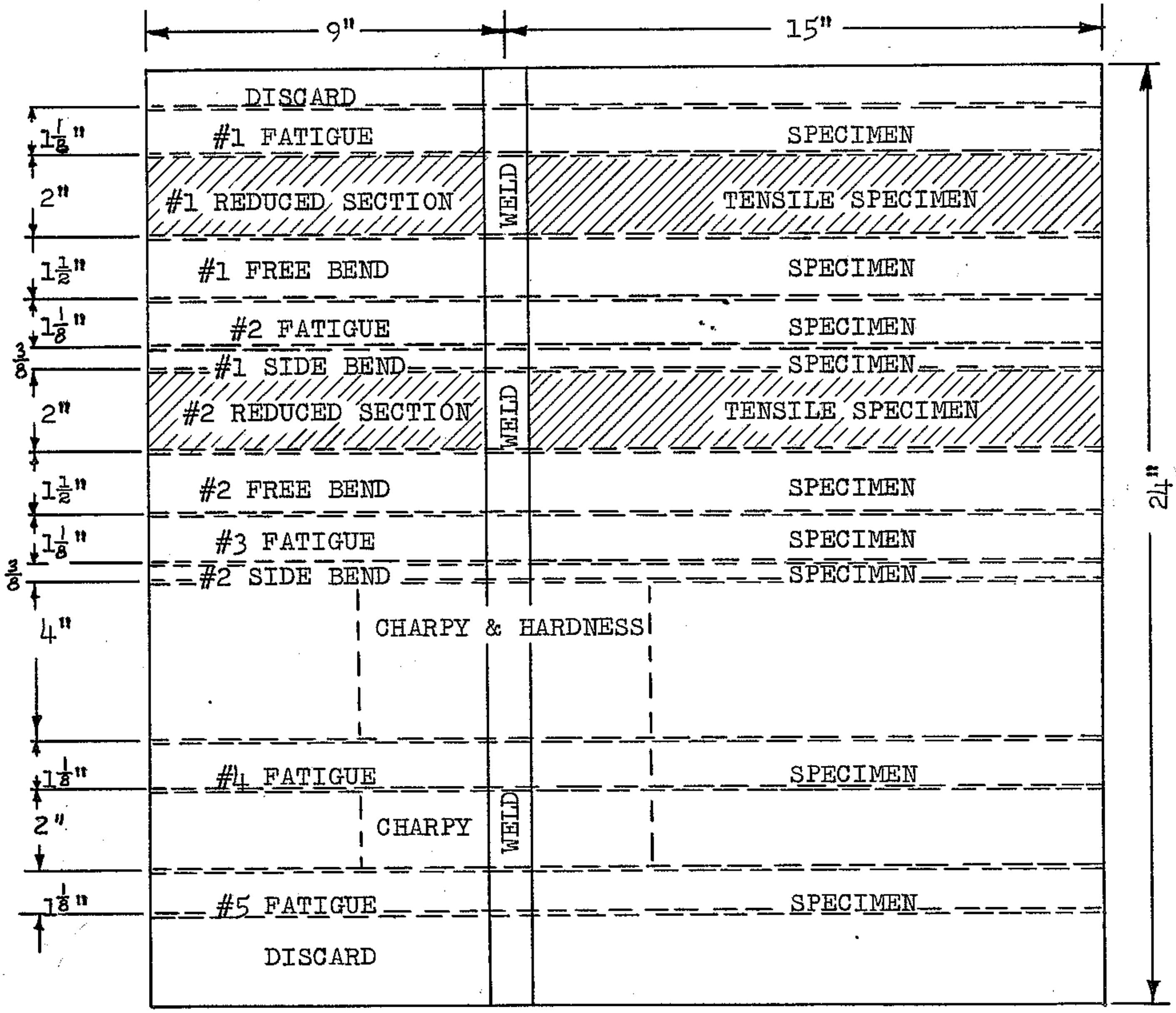


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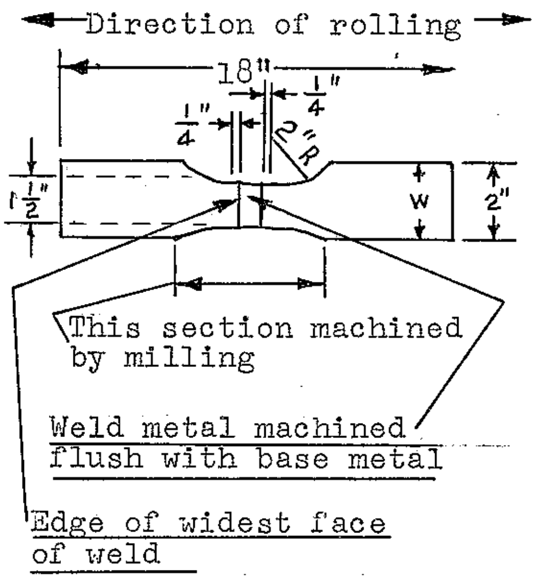
Exhibit 65

USS CARILLOY T-1 STEEL WELDED CONDITION TRANSVERSE BUTT WELDED --

MECHANICAL PROPERTIES

Spec. #	Electrodes Used	Welding Process Used	Yield psi	U. T. S. psi	% Elong. in in.	% Reduc. Area	Fatigue Endrance Limit psi	Plate Thickness in in.	Location of Failure
2-A-1	E-11016 (Tentative)	A.O.Smith SW - 91 Manual	not recorded	116,000	16%	28%		½"	H.A.Z.
2-A-2	"	"	"	119,200	11.5%	9.2%		½"	H.A.Z.
2-B-1	"	"	109,000	120,500	12%	17%	37,900	1"	Jct. Weld Met.& HAZ
2-B-2	"	"	111,400	122,900	19%	25%	37,900	1"	Weld Met. & Jct. HAZ & P.M.
2-C-1	"	"	86,800	97,000	35%	40%	37,900	1½"	Weld Met. & Jct. HAZ & P.M.
2-C-2	"	"	80,400	90,700	35%	50%	37,900	1½"	V Shape Jct. HAZ & PM
3-A-1	E-10016	Airco 353 Manual	93,000?	119,500	13%	20%	-	½"	H.A.Z.
3-A-2	"	"	not recorded	122,000	13%	16%	-	½"	H.A.Z.
3-B-1	"	"	95,000	110,900	20%	33%	32,900	1"	Weld Met.
3-B-2	"	"	107,200	123,300	20%	28%	32,900	1"	Weld Met.
3-C-1	"	"	83,700	95,300	37%	63%	32,900	1½"	Parent Metal
3-C-2	"	"	85,700	97,400	36%	60%	32,900	1½"	Parent Metal

Detail of standard Reduced-section tension specimens



Note: All specimens were cut by metal saw for width

HAZ & H.A.Z. = heat affected zone
Jct. = junction
Met. = metal
PM & P.M. = parent metal

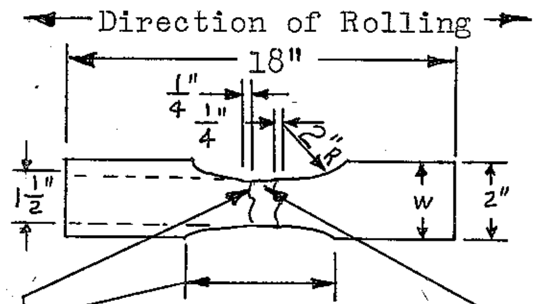
[illegible]

USS CARILLOY T-1 STEEL WELDED CONDITION TRANSVERSE BUTT WELDED--

MECHANICAL PROPERTIES

Spec. #	Electrodes Used	Welding Process Used	Yield psi	U. T. S. psi	% Elong. in in.	% Reduc. Area	Fatigue Endurance Limit psi	Plate Thickness in in.	Location of Failure
4-A-1	Oxweld 866-1/8"	Unionmelt. #80 Flux	93,000	115,000	18%	24%		½"	Center of weld mtl.
4-A-2	"	"	92,800	113,200	23%	35%		½"	Jct. of HAZ & P.M.
4-B-1	"	"	99,300	115,000	18%	26%	40,700	1"	Weld Metal
4-B-2	"	"	103,800	116,000	17%	21%	40,700	1"	" "
4-C-1	"	"	67,900	78,900	18%	34%	40,700	1½"	" "
4-C-2	"	"	90,000	102,500	35%	41%	40,700	1½"	From Jct. HAZ & P.M. Into W.M.
5-A-1	A 632	Aircomatic. Argon #2 gas shield	not recorded	126,500	12%	10%		½"	H.A.Z.
5-A-2	"	"	"	122,000	13%	13%		½"	H.A.Z.
5-B-1	"	"	102,300	125,200	23%	27%	39,800	1"	Jct. HAZ & P.M. into small part W.M.
5-B-2	"	"	104,000	121,800	25%	29%	39,800	1"	Jct. HAZ & P.M. into W.M.
5-C-1	"	"	90,000	101,200	27%	43%	39,800	1½"	Parent Metal
5-C-2	"	"	93,000	106,400	27%	40%	39,800	1½"	" "

Detail of Standard Reduced-section tension specimens



This section machined by milling

Weld metal machined flush with base metal

Edge of widest face of weld

Note: All specimens were cut by metal saw for width

HAZ & H.A.Z. = heat affected zone
mtl. = metal
Jct. = junction
P.M. = parent metal
W.M. = weld metal

Exhibit 66

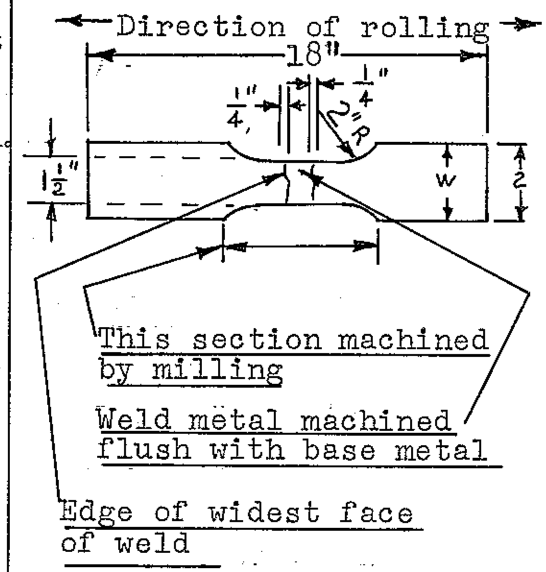
Exhibit 67

USS CARILLOY T-1 STEEL WELDED CONDITION TRANSVERSE BUTT WELDED --

MECHANICAL PROPERTIES

Spec. #	Electrodes Used	Welding Process Used	Yield psi	U. T. S. psi	% Elong. in 2"	% Reduc. Area	Fatigue Endurance Limit psi	Plate thickness in in.	Location of Failure
6-A-1	E-12015	Airco 352 Manual	100,600	118,600	20%	32%		½"	Weld Mtl. thru HAZ to Parent Metal
6-A-2	"	"	100,500	121,200	23%	33%		½"	Weld Mtl.
6-B-1	"	"	110,500	116,300	18%	15%	32,700	1"	V Shape Jct. HAZ & P.M.
6-B-2	"	"	110,200	124,600	17%	16%	32,700	1"	Jct. HAZ & P.M. small part W.M.
6-C-1	"	"	85,800	95,600	25%	48%	32,700	1½"	P.M.
6-C-2	"	"	87,300	98,700	26%	46%	32,700	1½"	P.M.

Detail of standard Reduced-section tension specimens



Note: All specimens were cut by metal saw for width

HAZ = heat affected zone
Mtl. = metal
P.M. = parent metal
W.M. = weld metal
Jct. = junction

[illegible]

MANUAL WELDING

TENSILE FAILURE PHOTOGRAPHS

OF

TRANSVERSE BUTT WELDS

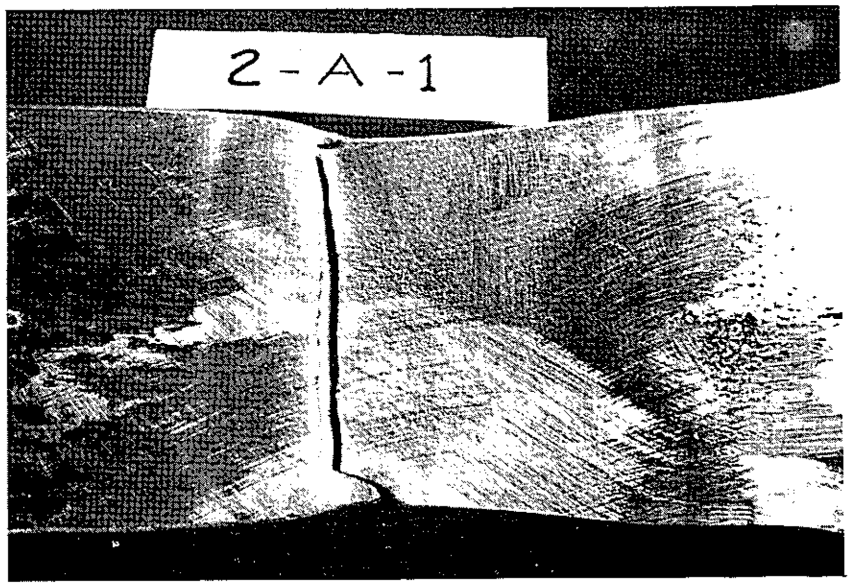
MADE WITH

A.O. SMITH

S.W. 91, LOW HYDROGEN ELECTRODES

(E-11016 TENTATIVE)

Exhibit 68



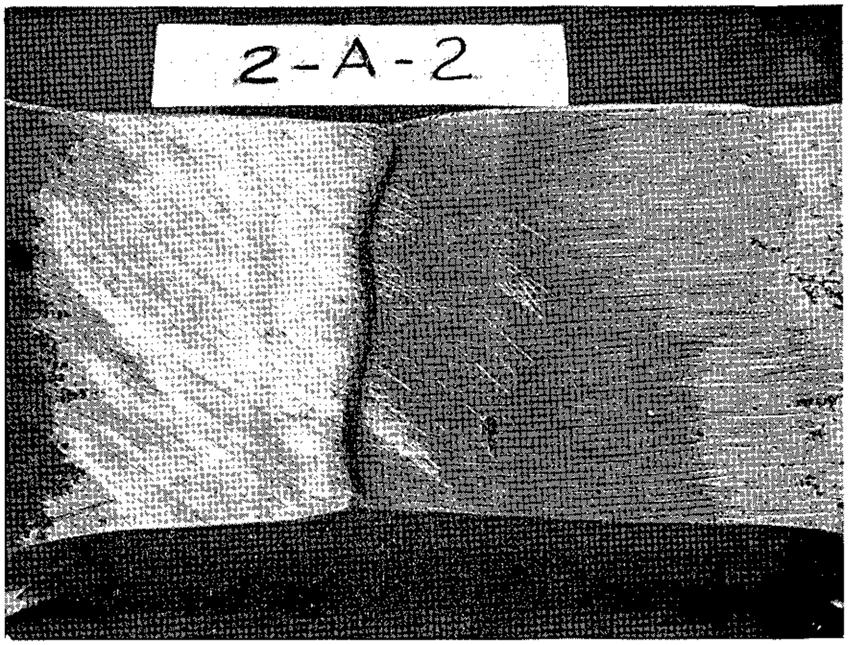
Face view

2" strap tensile test on 1/2" butt joint
welded using the A. O. Smith process
Yield   not recorded
Ultimate 116,000 psi
2" elongation   16%
Red Area   28%

Failure in heat affected zone

End view

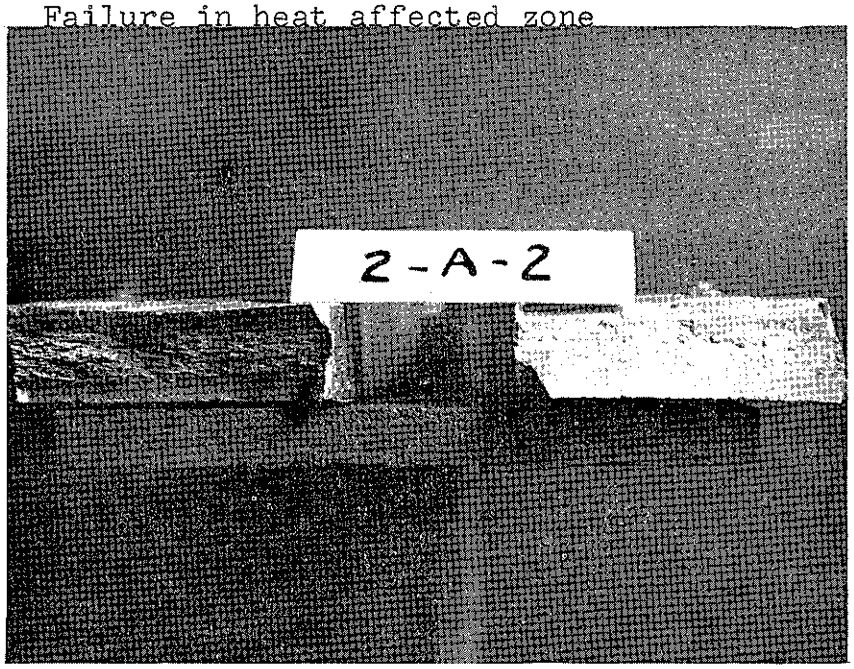
Note rolling structure



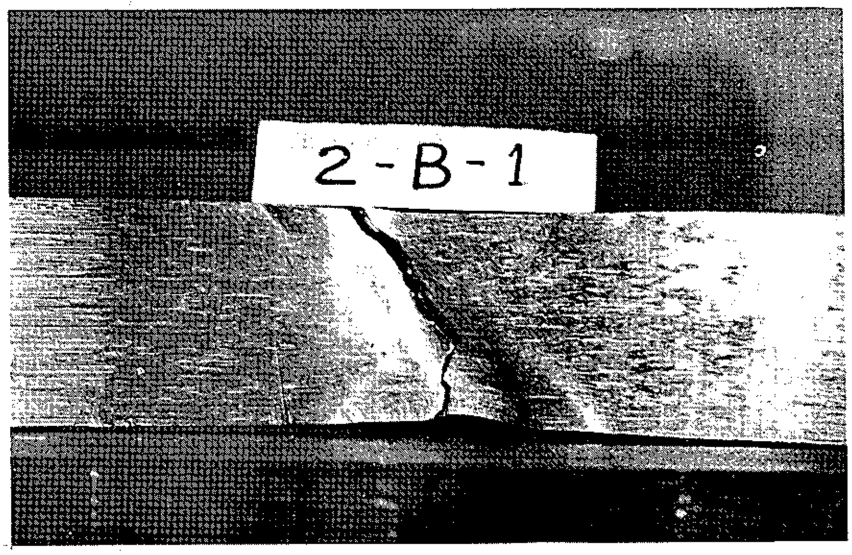
Face view

2" strap tensile test on 1/2" butt joint welded
using the A. O. Smith process
Yield not recorded
Ultimate 119,200 psi
2" elongation 11.5 %
Red Area 9.0 %

Failure in heat affected zone



End view
Note rolling structure

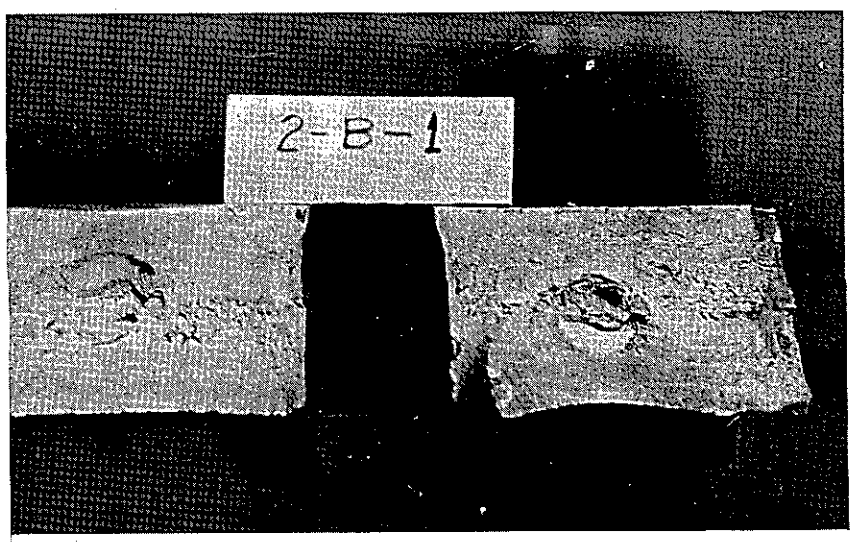


Side view

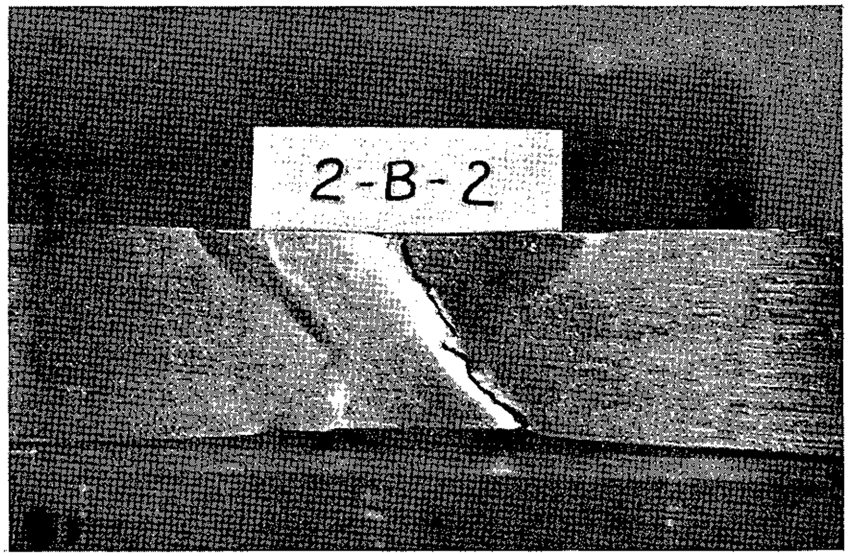
2" strap tensile test on 1" butt joint welded using the A. O. Smith process

Yield	109,000 psi
Ultimate	120,500 psi
2" Elongation	12%
Red Area	17%

Failure in heat affected zone and weld metal



End view
Note large slag inclusion

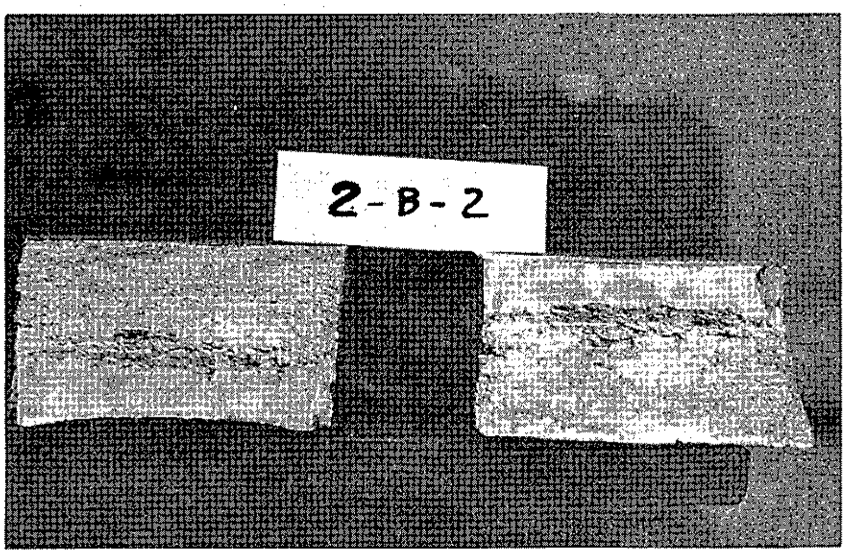


Side View

2" strap tensile test on 1" butt joint
welded using the A. O. Smith process

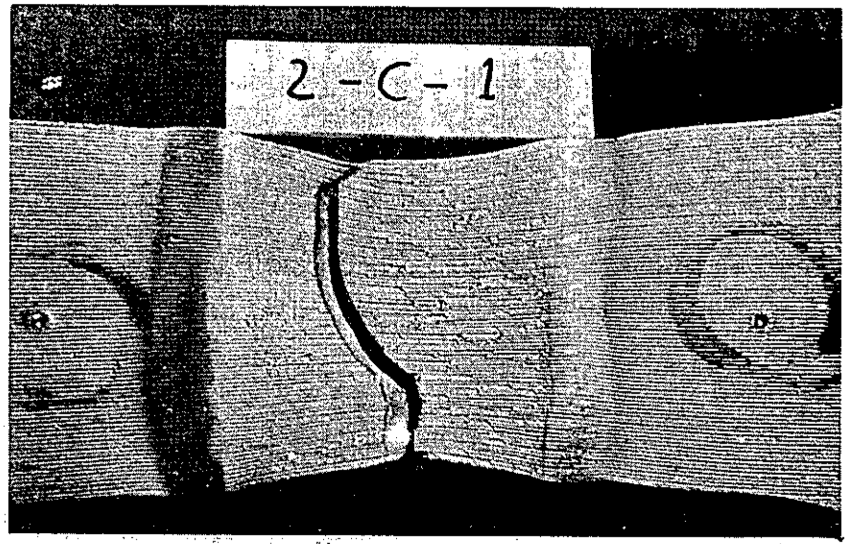
Yield	111,400 psi
Ultimate	122,900 psi
2" Elongation	19%
Red Area	25%

Failure in heat affected zone

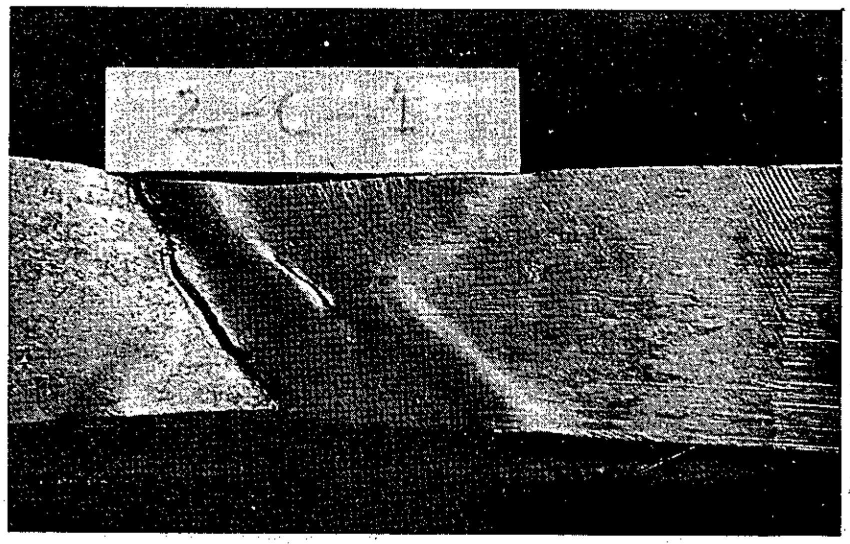


End View

Exhibit 72



Face view

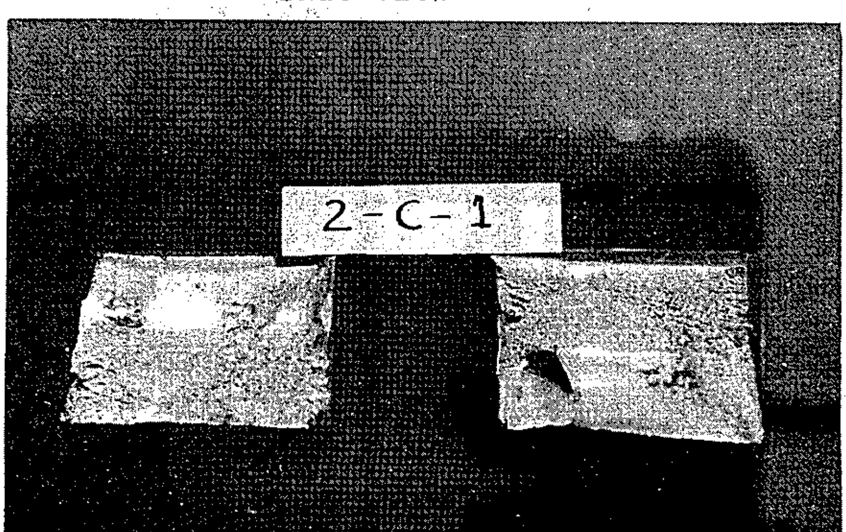


2" strap tensile test on 1 1/2" butt joint welded using the A. O. Smith process.

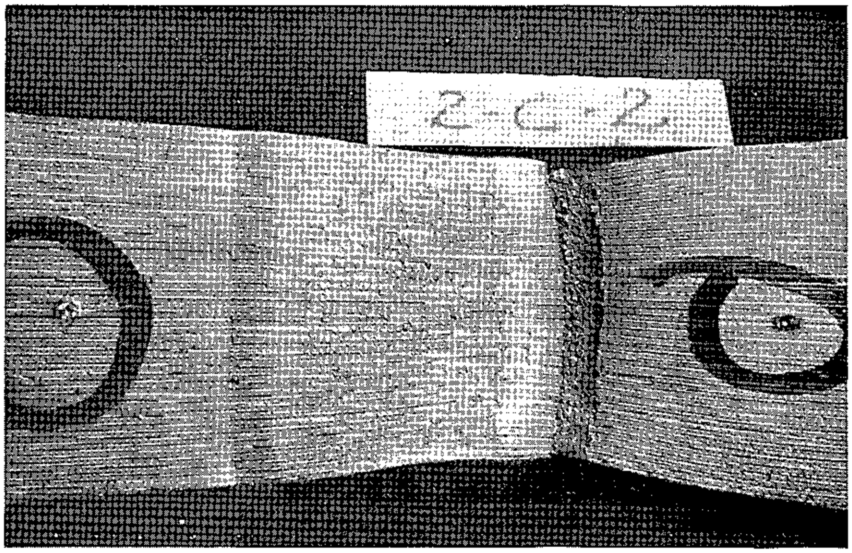
Yield	86,800 psi
Ultimate	97,000 psi
2" elongation	35 %
Red Area	40 %

Failure in weld and heat affected zone

Side view



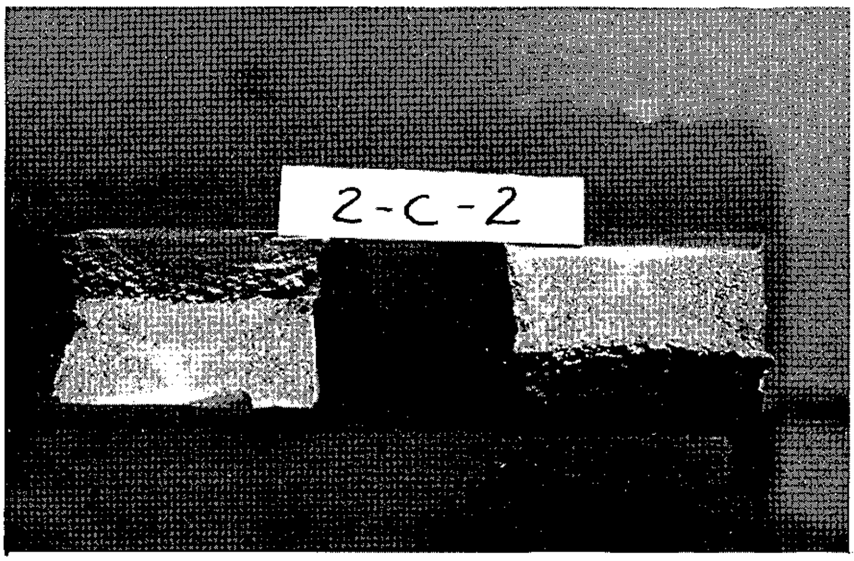
End view
Note slag inclusion



Face view

2" strap tensile test on 1 1/2" butt joint
using the A. O. Smith process
Yield 80,400 psi
Ultimate 90,700 psi
2" elongation 35 %
Red Area 50 %

Failure in heat affected zone



End view

MANUAL WELDING

TENSILE FAILURE PHOTOGRAPHS

OF

TRANSVERSE BUTT WELDS

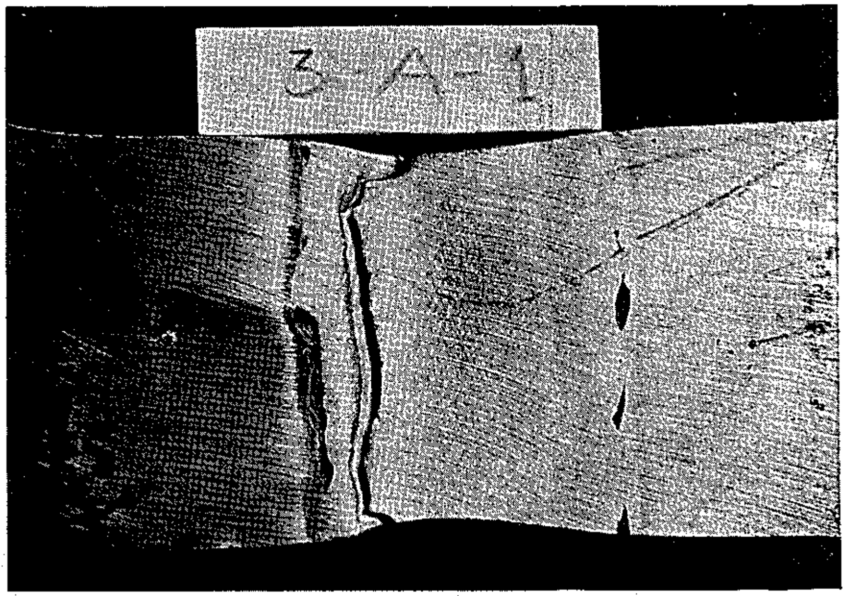
MADE WITH

AIRCO

353, LOW HYDROGEN ELECTRODES

(E-10016)

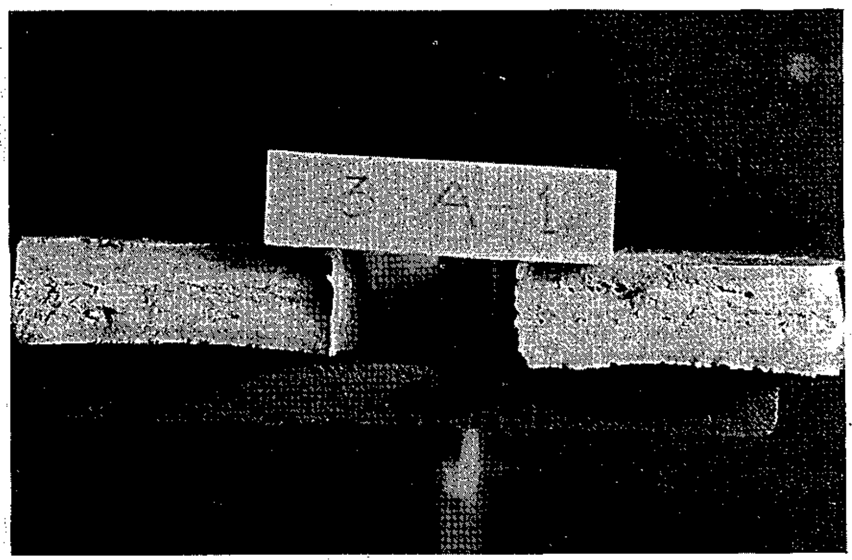
Exhibit 74



Face view

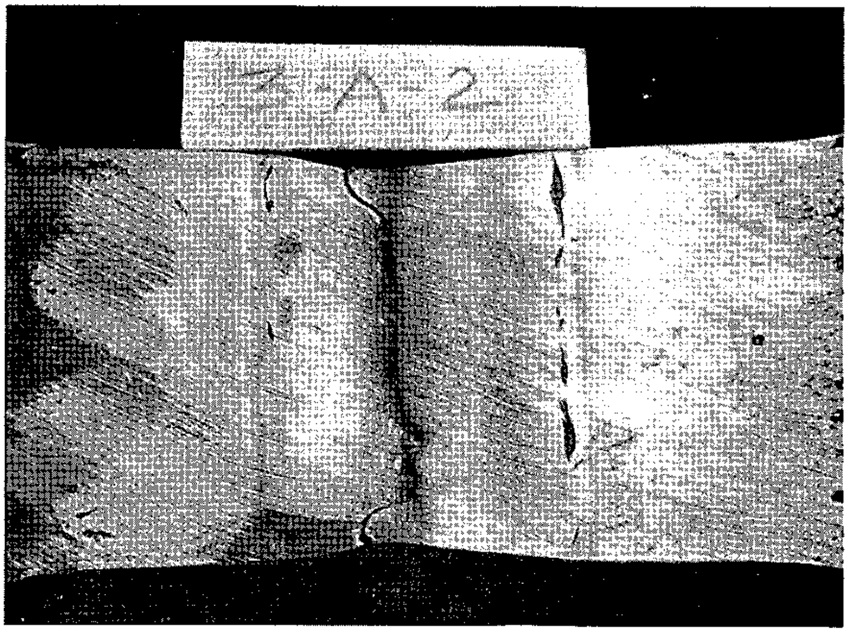
2" strap tensile test on 1/2" butt joint
manually welded using Airco 353 electrodes
Yield 93,000 psi
Ultimate 119,500 psi
2" elongation 13%
Red Area 20%

Failure in heat affected zone



End view

Note numerous pinhole inclusions in
weld metal

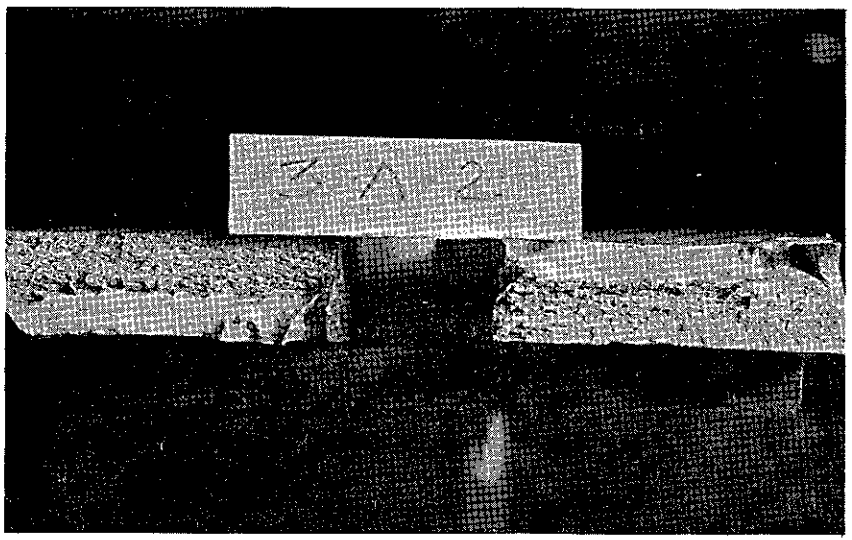


Face view

2" strap tensile test on 1/2" butt joint
manually welded using Airco 353 electrodes

Yield	not recorded
Ultimate	122,000 psi
2" elongation	13 %
Red Area	16%

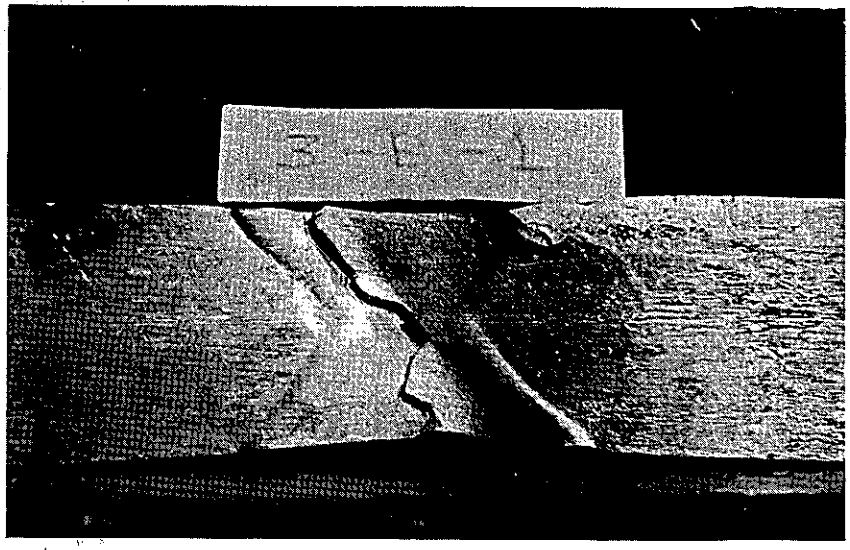
Failure in heat affected zone



End view

Note fish eye void and rolling structure

Exhibit 76

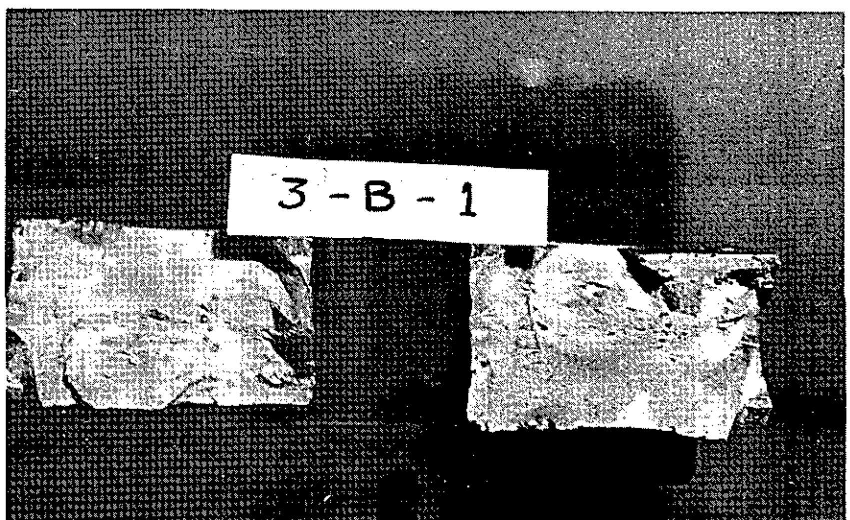


Side view

2" strap tensile of 1" butt joint manually
welded using Airco 353 electrodes

Yield	95,000 psi
Ultimate	110,900 psi
2" Elongation	20%
Red Area	33%

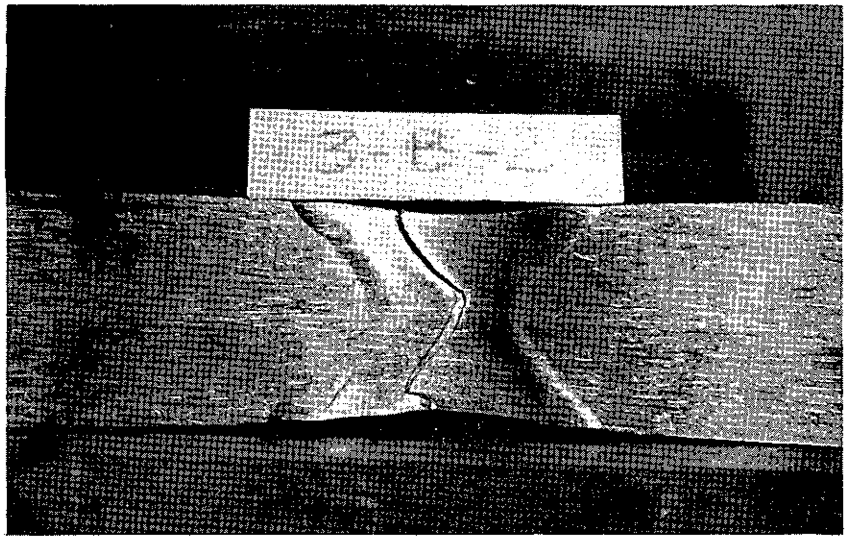
Failure in Weld Metal



End view

Note numerous inclusions in fracture section

Exhibit 77

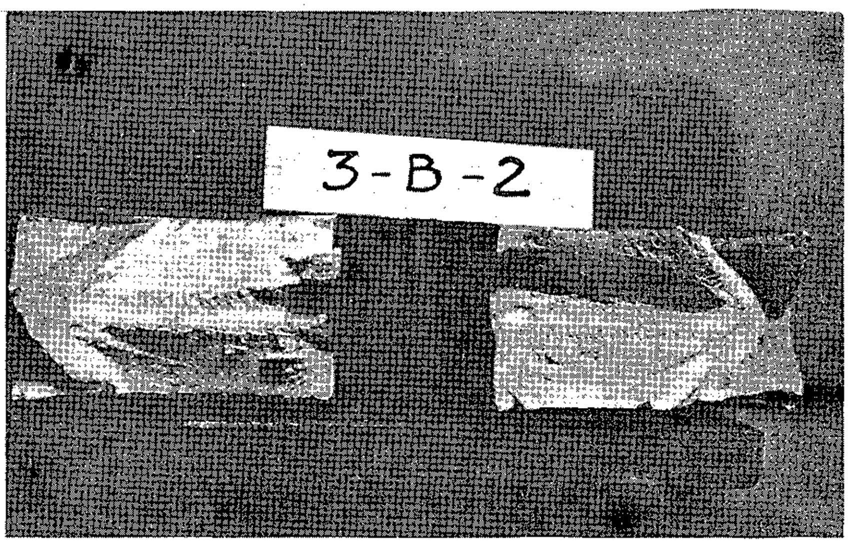


Face view

2" strap tensile test of 1" butt joint manually welded using Airco 353 electrodes

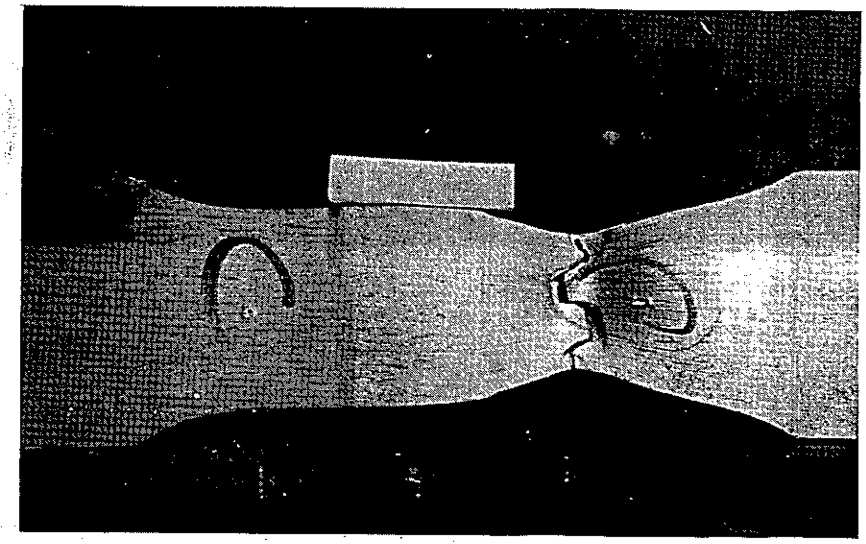
Yield	107,200 psi
Ultimate	123,300 psi
2" Elongation	20%
Red Area	28%

Failure in weld metal



End view

Exhibit 78



Side view

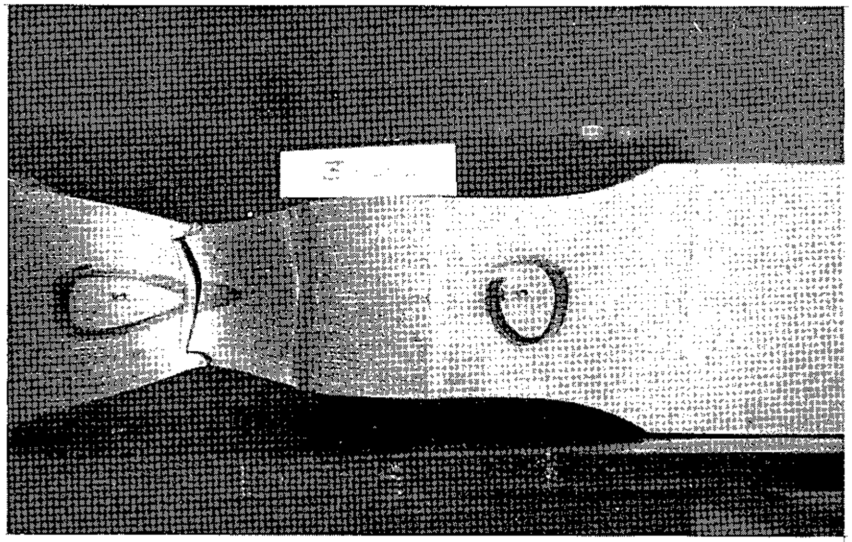
2" strap tensile of 1 1/2" butt joint manually welded using Airco 353 electrodes

Yield	83,700 psi
Ultimate	95,300 psi
2" elongation	37 %
Red Area	63 %

Failure in parent metal

End view

Note parallel shear

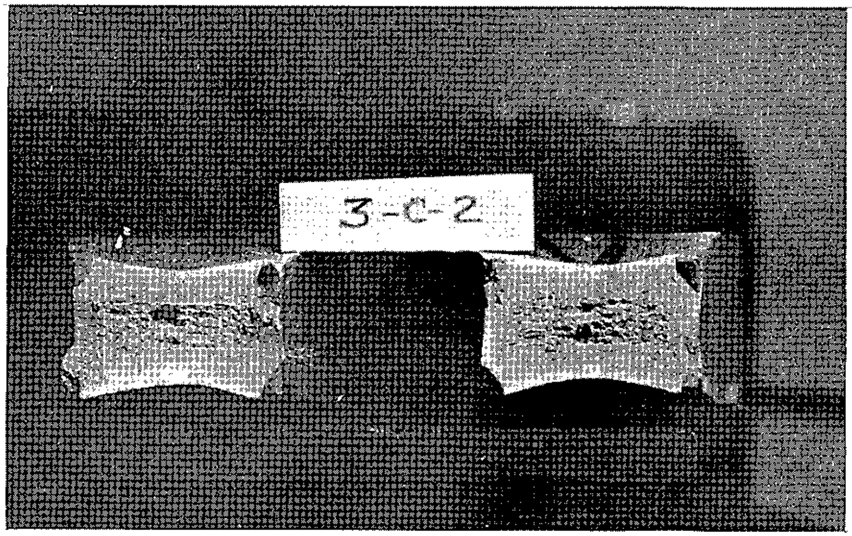


Side view

2" strap tensile of 1 1/2" butt joint manually welded using Airco 353 electrodes.

Yield 85,700 psi
Ultimate 97,400 psi
2" elongation 36 %
Red Area 60 %

Failure in parent metal



End view

AUTOMATIC WELDING

TENSILE FAILURE PHOTOGRAPHS

OF

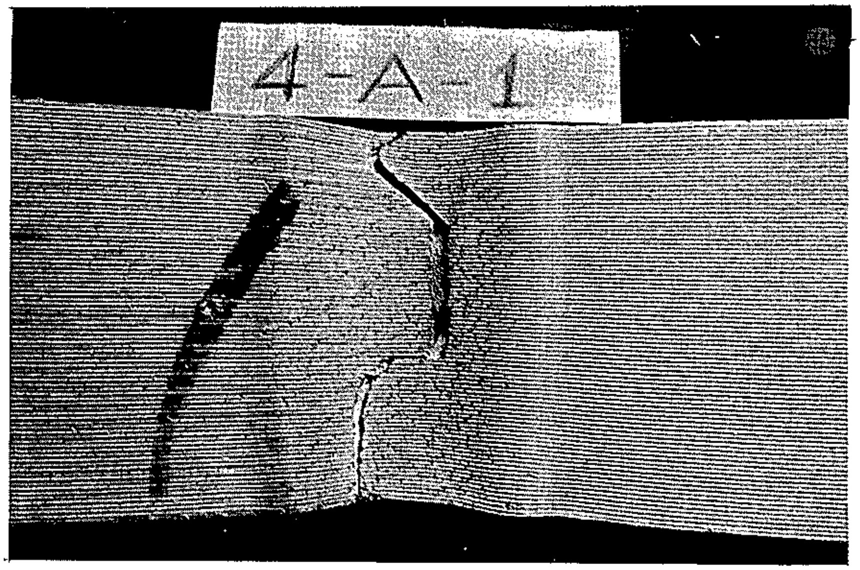
TRANSVERSE BUTT WELDS

MADE WITH

UNIONMELT SUBMERGED ARC PROCESS

WITH

OXWELD 866 ELECTRODE WIRE AND 80 FLUX

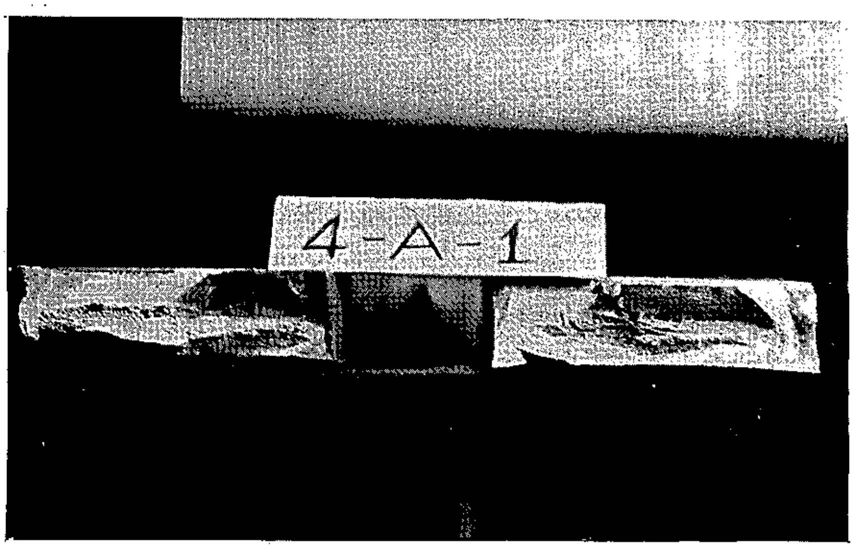


Face view

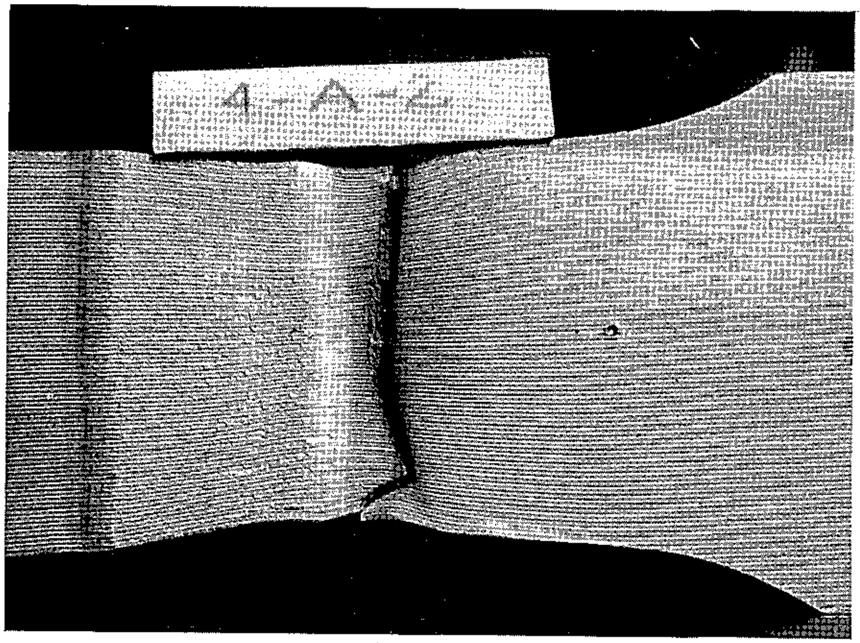
2" strap tensile test of 1/2" butt joint
welded using the Unionmelt process

Yield 93,000 psi
Ultimate 115,000 psi
2" elongation 18 %
Red Area 24 %

Failure in weld metal



End view

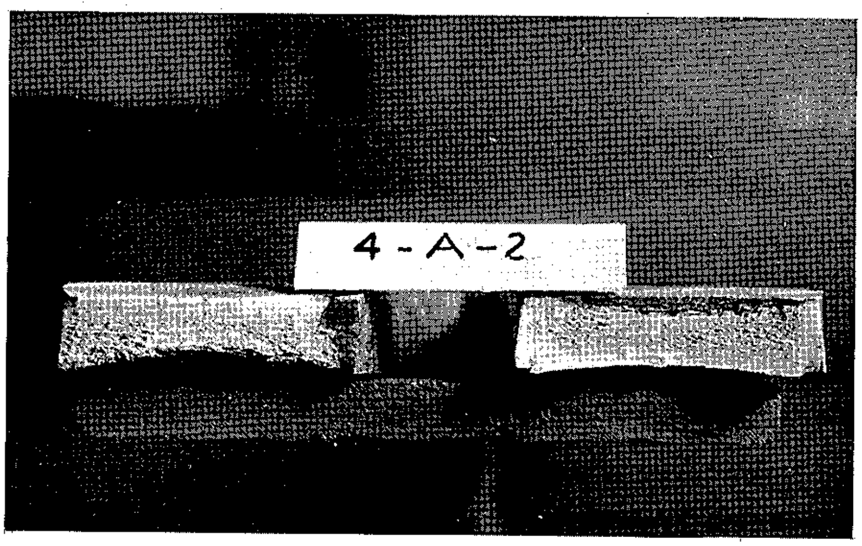


Face view

2" strap tensile test on 1/2" butt joint
welded using the Unionmelt process

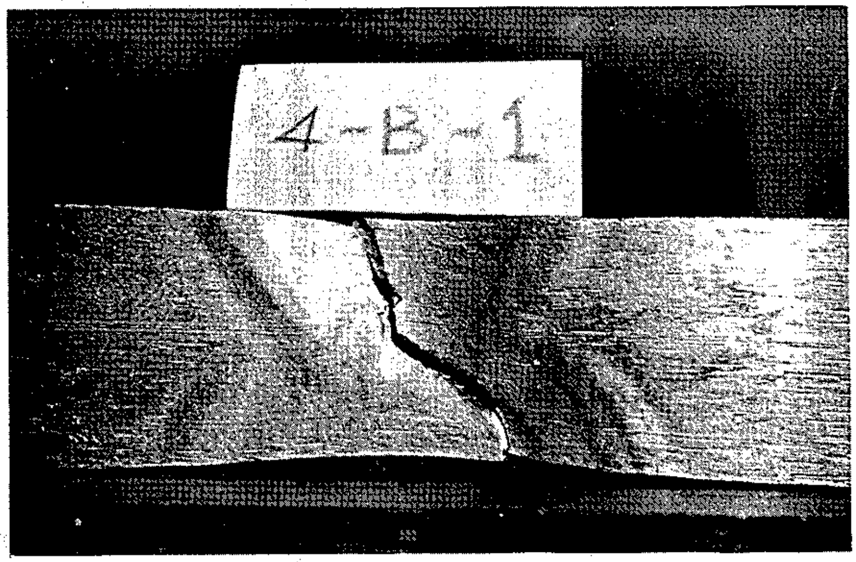
Yield	92,800 psi
Ultimate	113,200 psi
2" elongation	23 %
Red Area	35 %

Failure in parent metal



End view
Note rolling structure

Exhibit 82

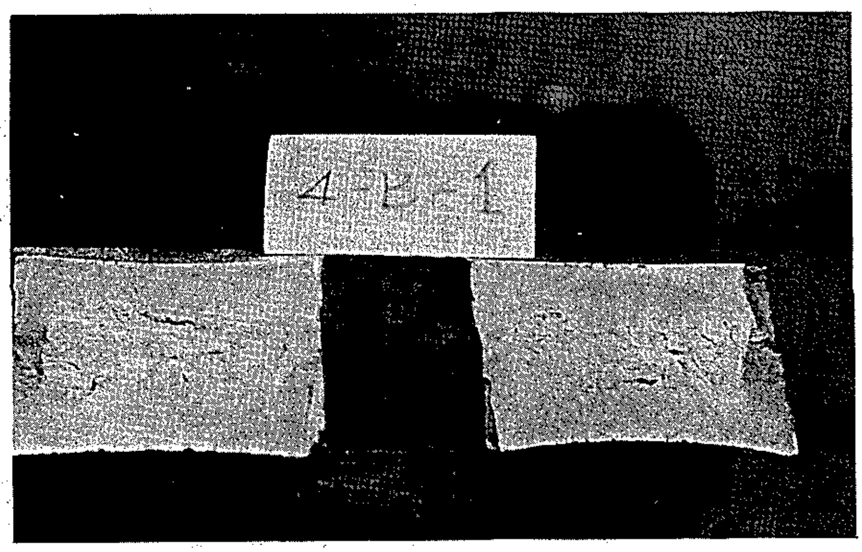


Side view

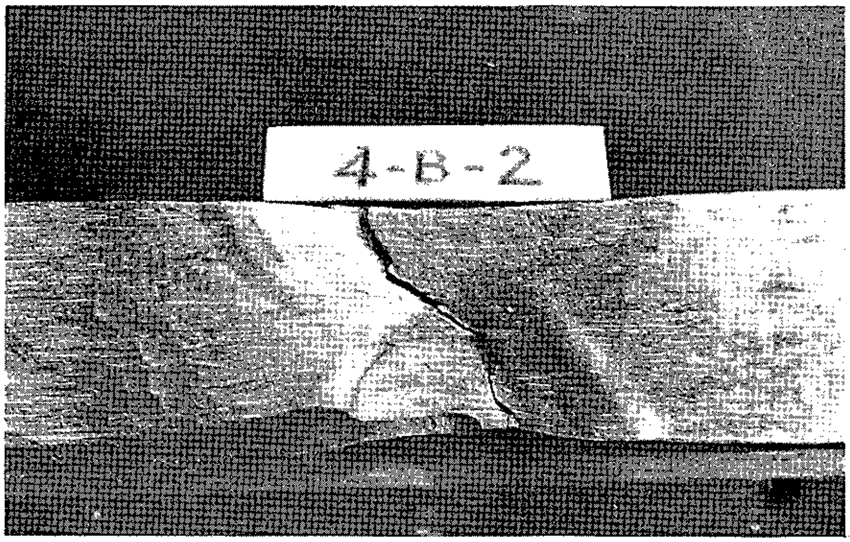
2" strap tensile test of 1" butt joint welded
using the Unionmelt process

Yield	99,300 psi
Ultimate	115,000 psi
2" elongation	18 %
Red Area	26 %

Failure in weld metal.



End view

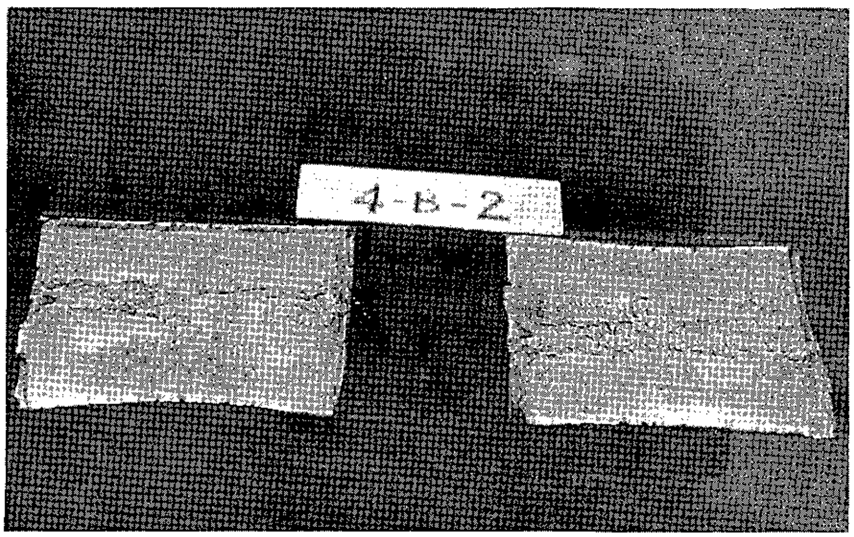


Side view

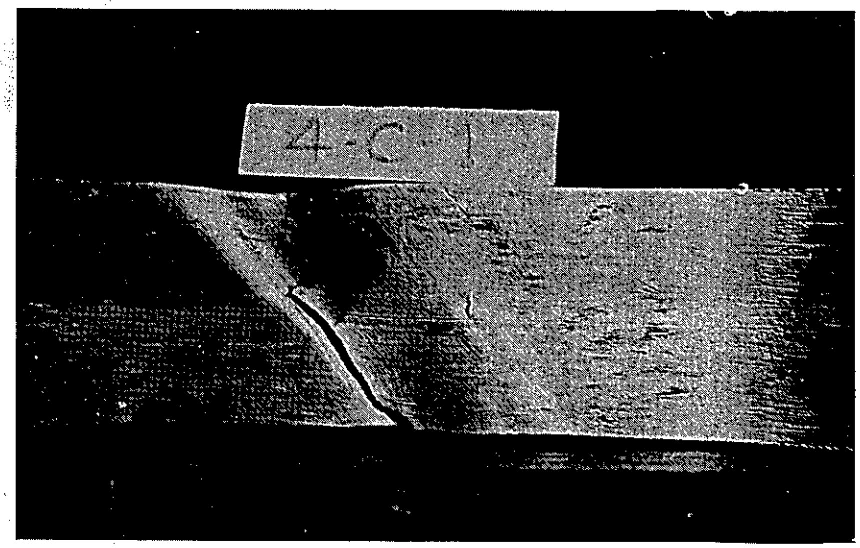
2" strap tensile on 1" butt joint welded using the Unionmelt process

Yield	103,800 psi	
Ultimate	116,000 psi	
2" elongation		17 %
Red Area		21 %

Failure in weld metal



End view

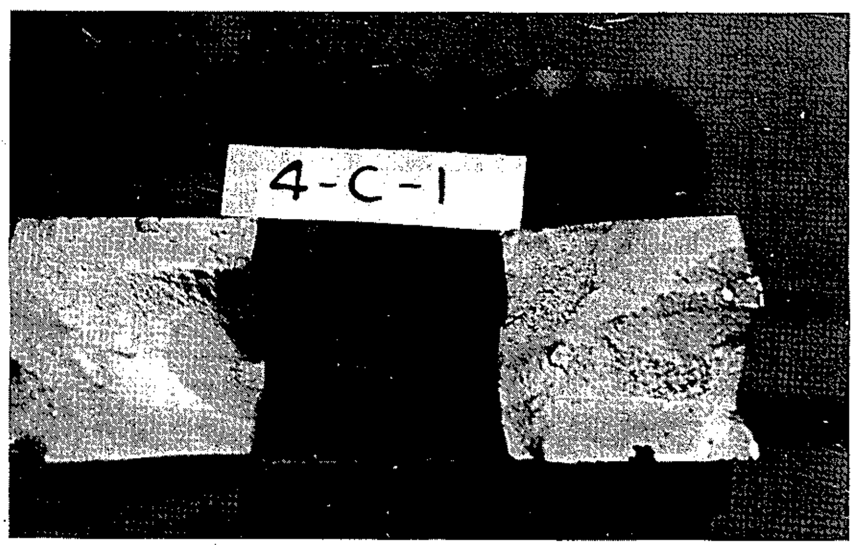


Side view

2" strap tensile test of 1 1/2" butt joint
welded using the Unionmelt process

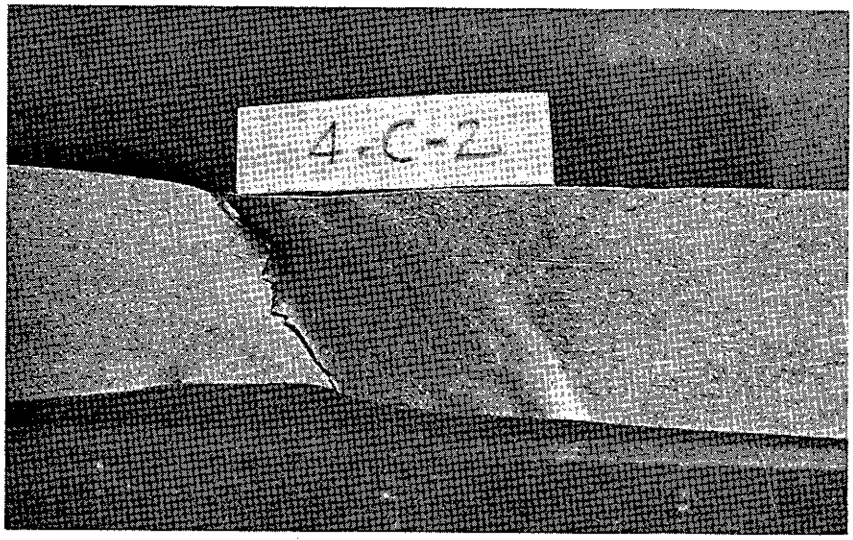
Yield	67,900 psi
Ultimate	78,900 psi
2" elongation	18 %
Red Area	34 %

Failure in weld metal



End view

Note extensive separation responsible for
low strength of weld

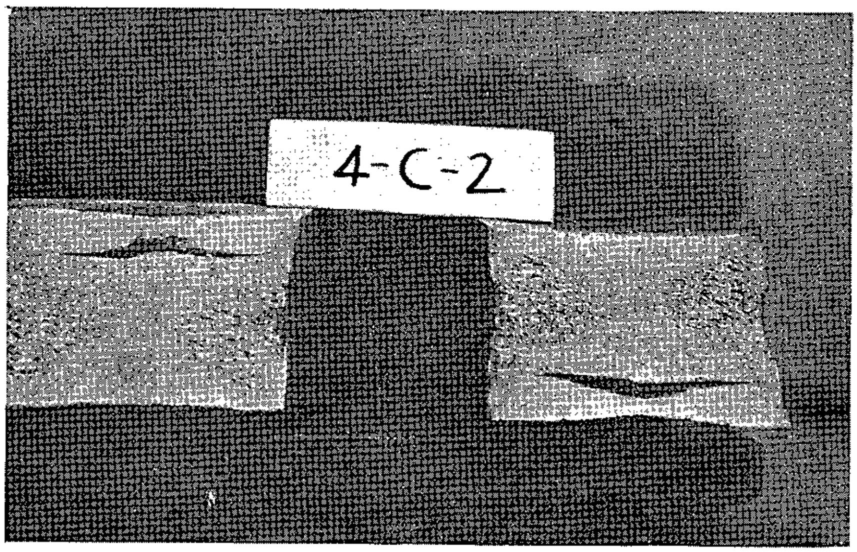


Side view

2" strap tensile test of 1 1/2" butt joint
welded using the Unionmelt process

Yield	90,000 psi
Ultimate	102,500 psi
2" elongation	35 %
Red Area	41 %

Failure in weld metal and heat affected zone



End view

SEMI-AUTOMATIC WELDING

TENSILE FAILURE PHOTOGRAPHS

OF

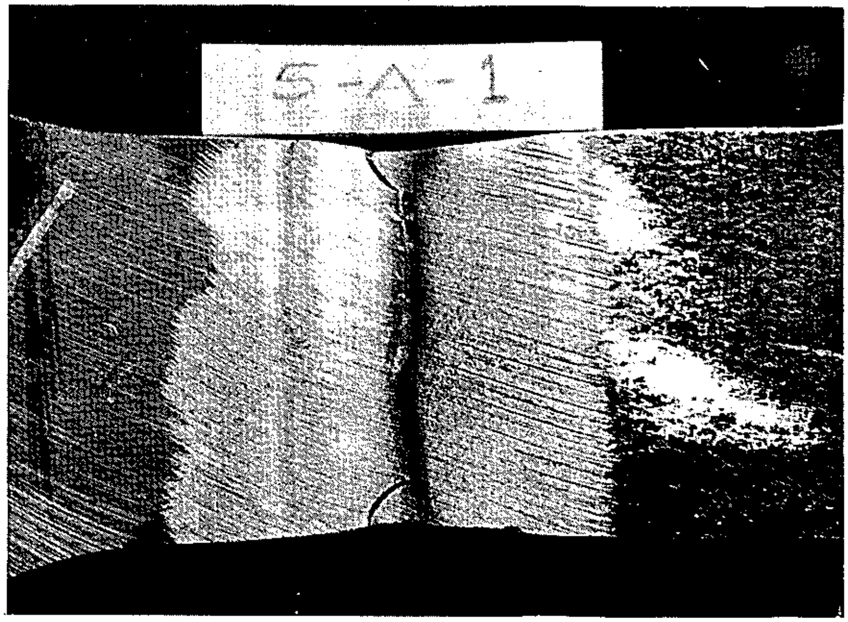
TRANSVERSE BUTT WELD

MADE WITH

AIRCOMATIC INERT GAS SHIELDED ARC PROCESS

WITH

A632 ELECTRODE WIRE AND A 98%A - 2%O_2 SHIELD

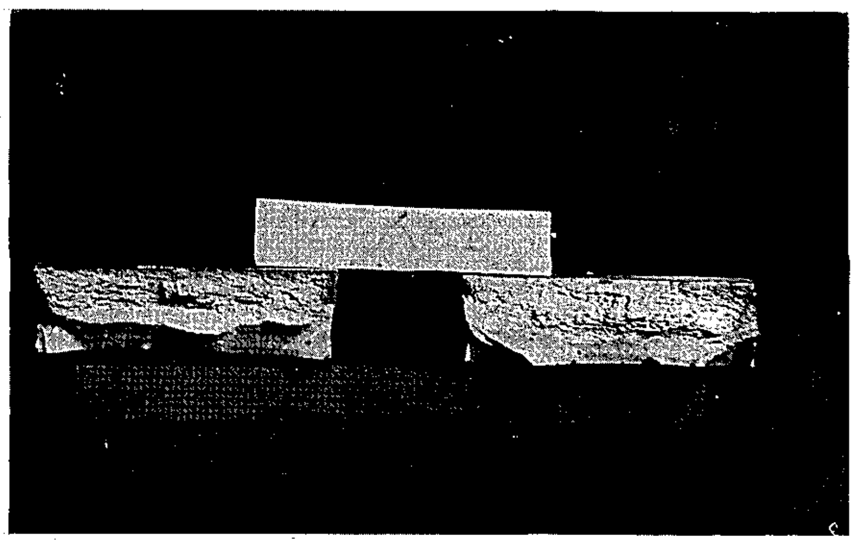


Face view

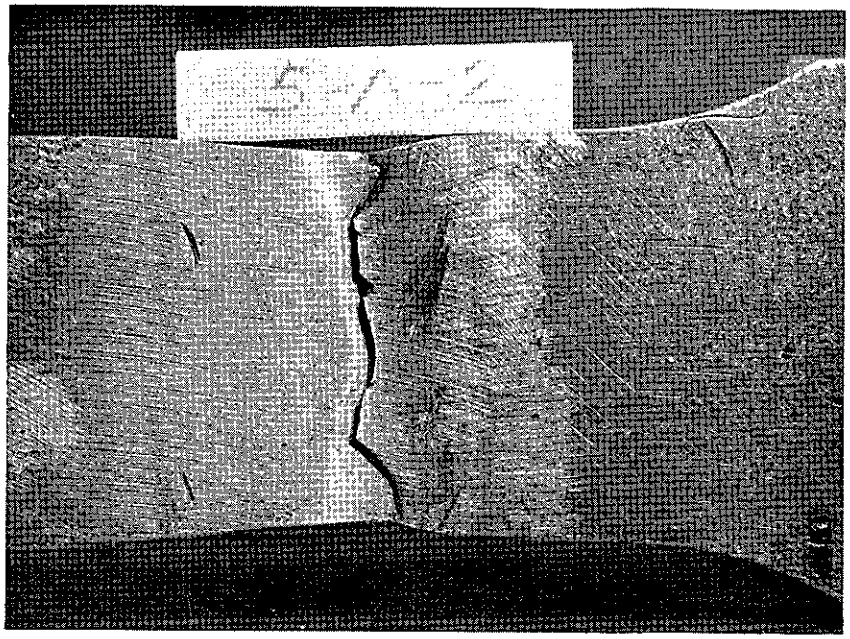
2" strap tensile test of butt joint welded using the Aircomatic process ($\frac{1}{2}$" joint)

Yield	not recorded
Ultimate	126,500 psi
2" elongation	12 %
Red Area	10 %

Failure in heat affected zone



Side view

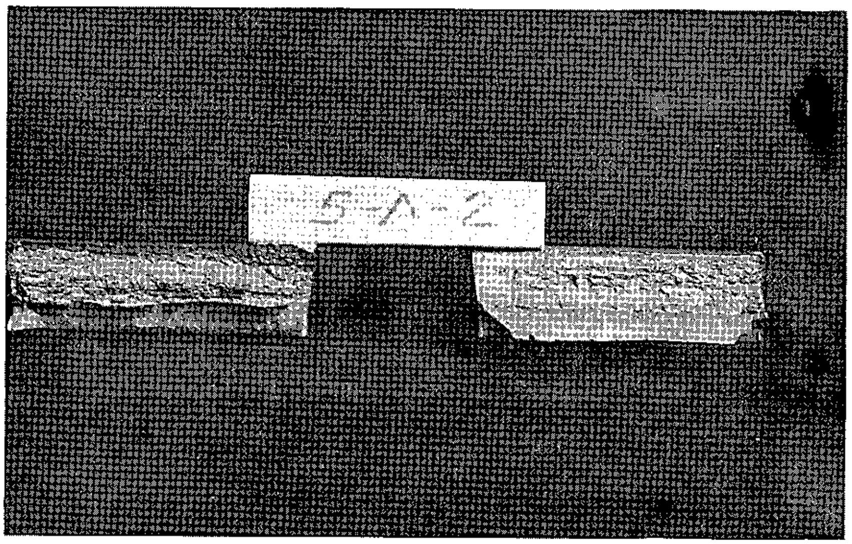


Face view

2" strap tensile test of 1/2" butt joint
welded using the Aircomatic process

Yield	not recorded
Ultimate	122,000 psi
2" elongation	13 %
Red Area	13 %

Failure in heat affected zone



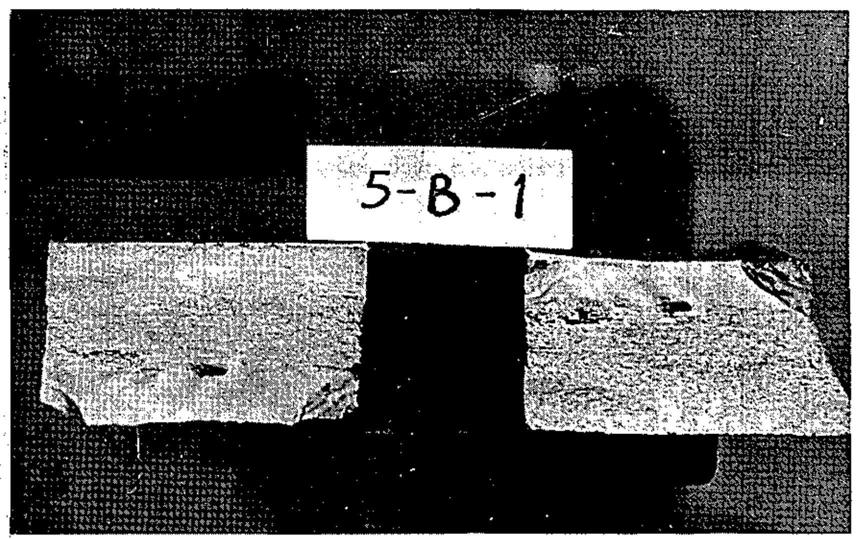
End view
Note rolling structure

Side view

2" strap tensile test of 1" butt joint
welded using the Aircomatic process

Yield	102,300 psi
Ultimate	125,200 psi
2" elongation	23 %
Red Area	27 %

Failure in heat affected zone



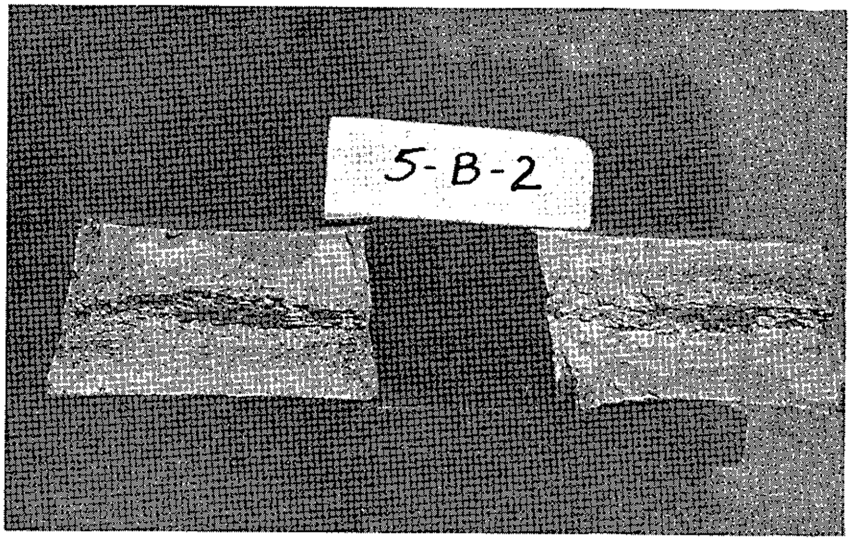
End view

Side view

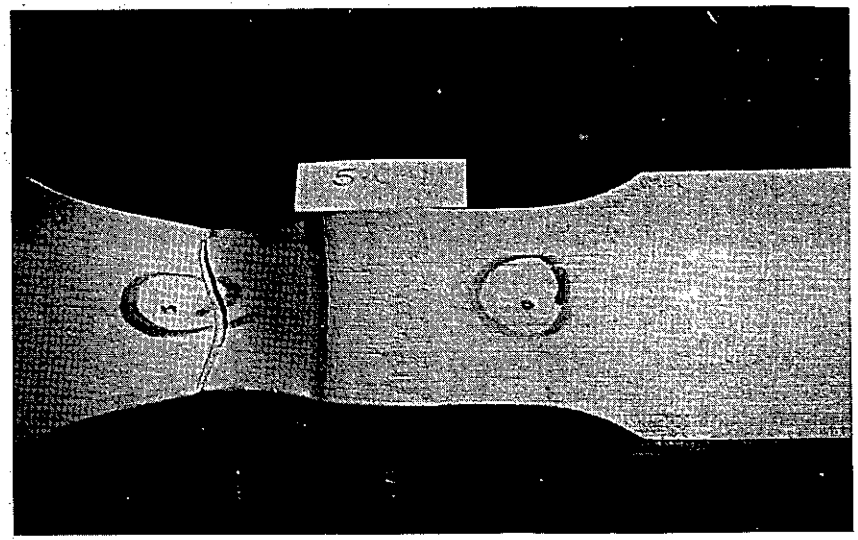
2" strap tensile test of 1" butt joint welded
with the Aircomatic gas shielded arc process
using A632 electrodes

Yield	104,000 psi
Ultimate	121,800 psi
2" elongation	25 %
Red Area	29 %

Failure initiated in heat affected zone



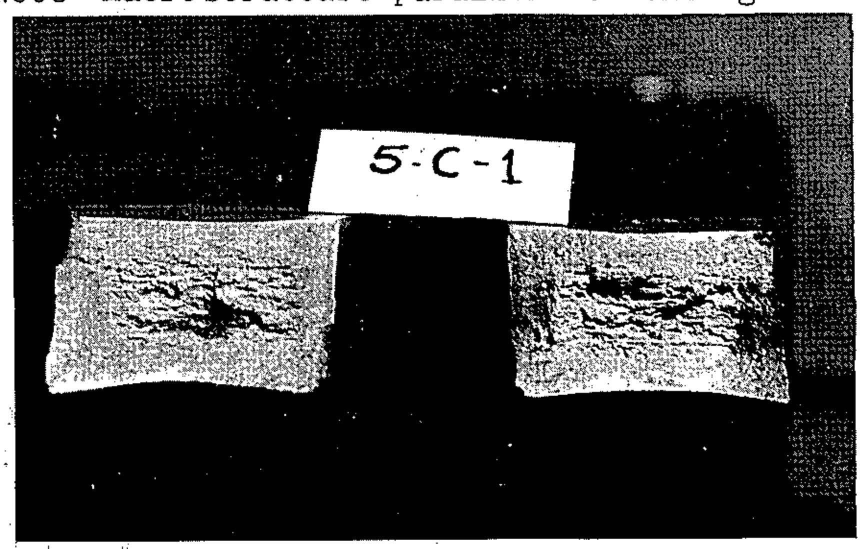
End view



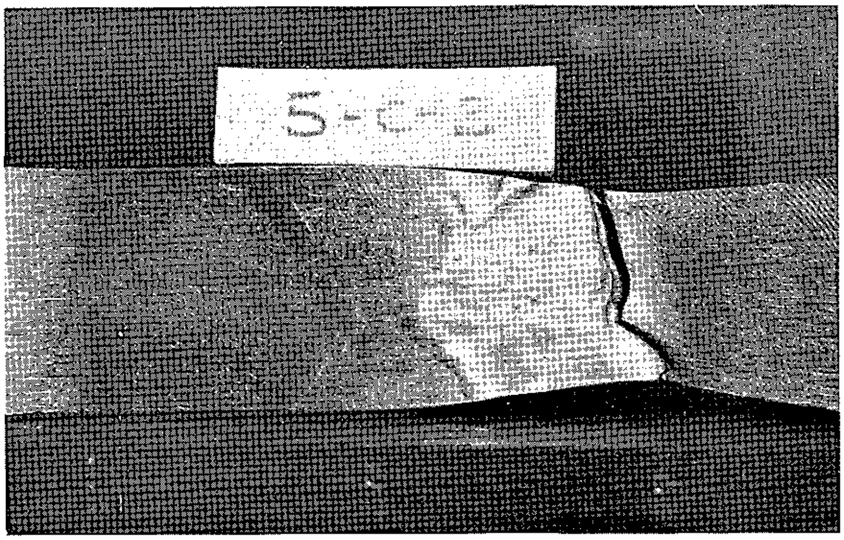
Face view

2" strap tensile test of 1 1/2" plate welded
using the Aircomatic process
Yield 90,000 psi
Ultimate 101,200 psi
2" elongation 27 %
Red Area 43 %

Failure in parent metal
Note Macrostructure parallel to rolling direction



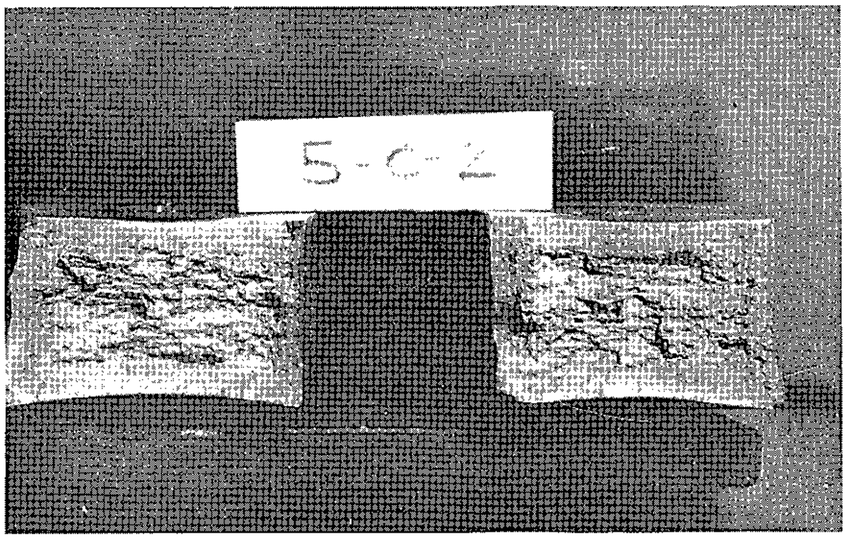
End view



Side view

2" strap tensile test of 1 1/2" butt joint
welded using the Aircomatic process
Yield 93,000 psi
Ultimate 106,400 psi
2" elongation 27 %
Red Area 40 %

Failure in parent metal
Note Macrostructure parallel to rolling direction



End view

MANUAL WELDING

TENSILE FAILURE PHOTOGRAPHS

OF

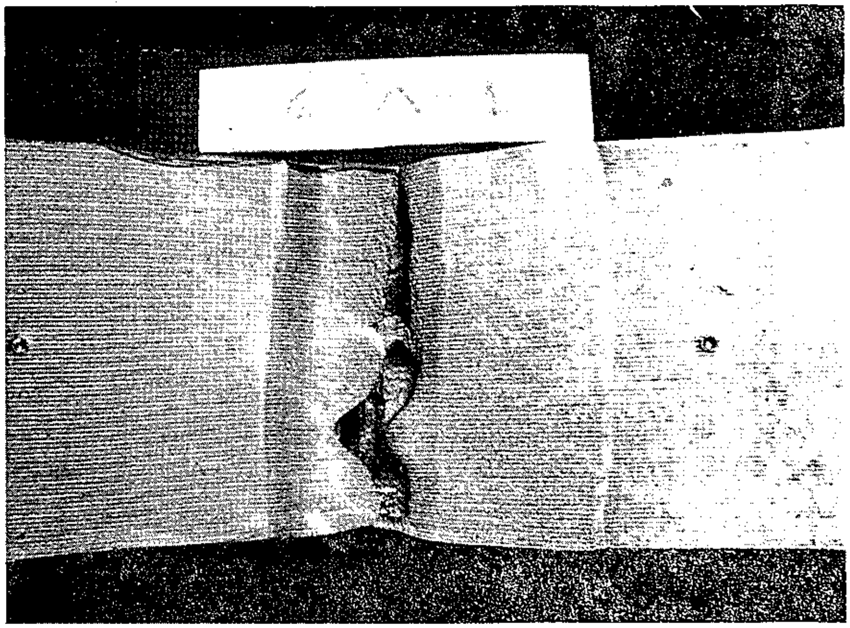
TRANSVERSE BUTT WELDS

MADE WITH

AIRCO

352, LOW HYDROGEN ELECTRODES

(E-10016)

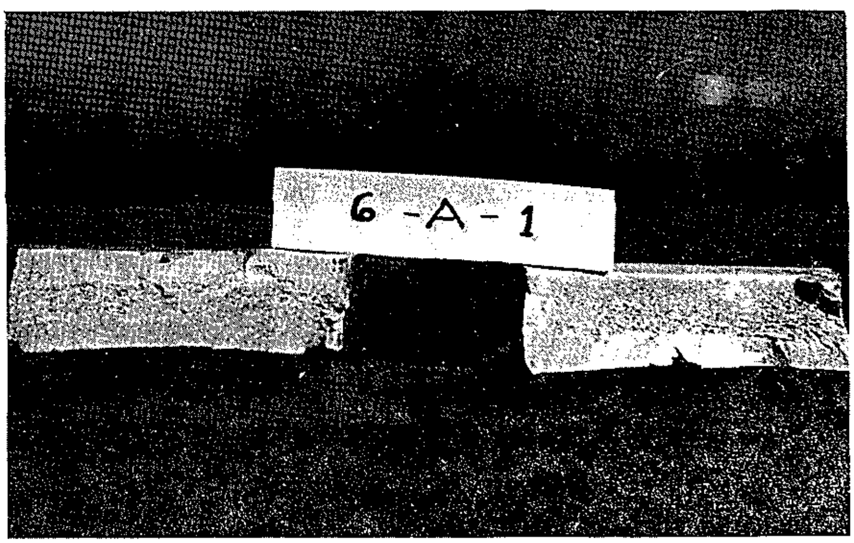


Face view

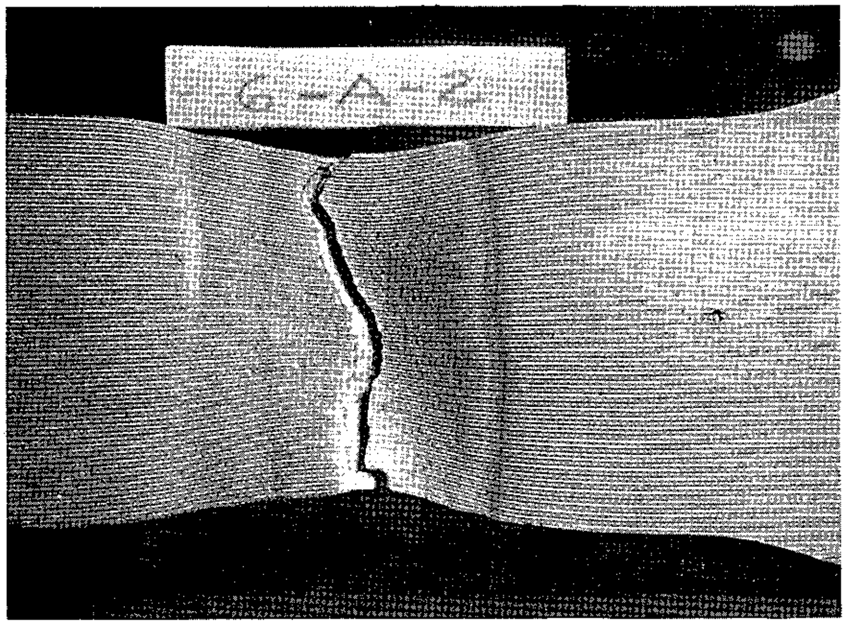
2" strap tensile test of 1/2" butt joint
manually welded using Airco 352 electrodes

Yield	100,600 psi
Ultimate	118,600 psi
2" elongation	20 %
Red Area	32 %

Failure in heat affected zone



End view
Note porous area similar to fisheye

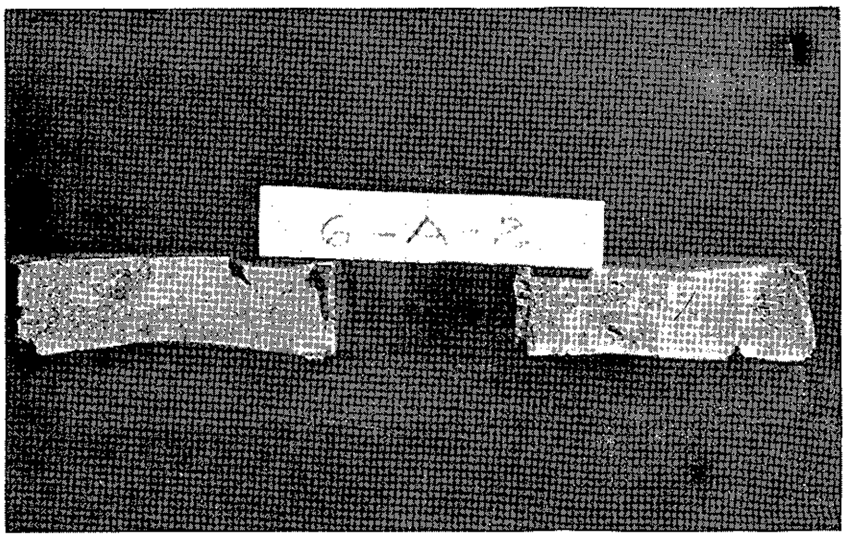


Face view

2" tensile test on 1/2" butt joint manually welded using Airco 352 electrodes

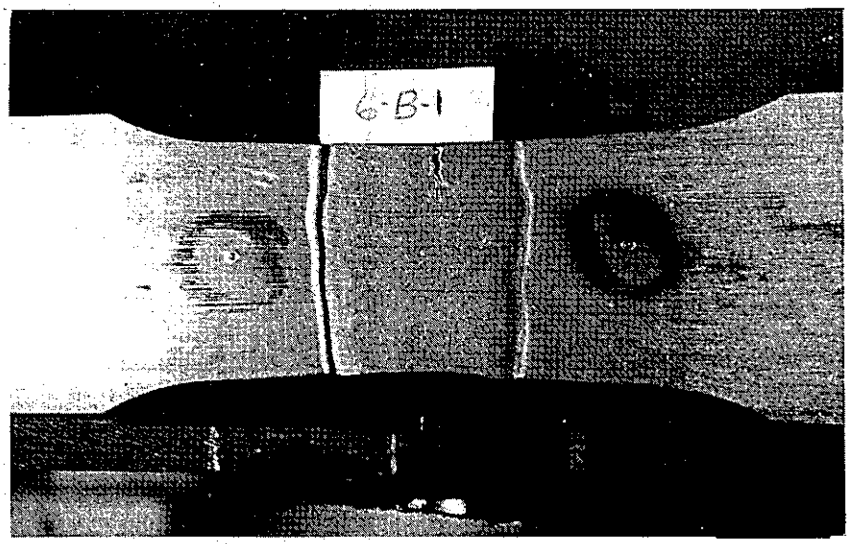
Yield	100,500 psi
Ultimate	121,200 psi
2" elongation	23 %
Red Area	33 %

Failure in weld metal



End view
Note void left by gas bubble

Exhibit 94



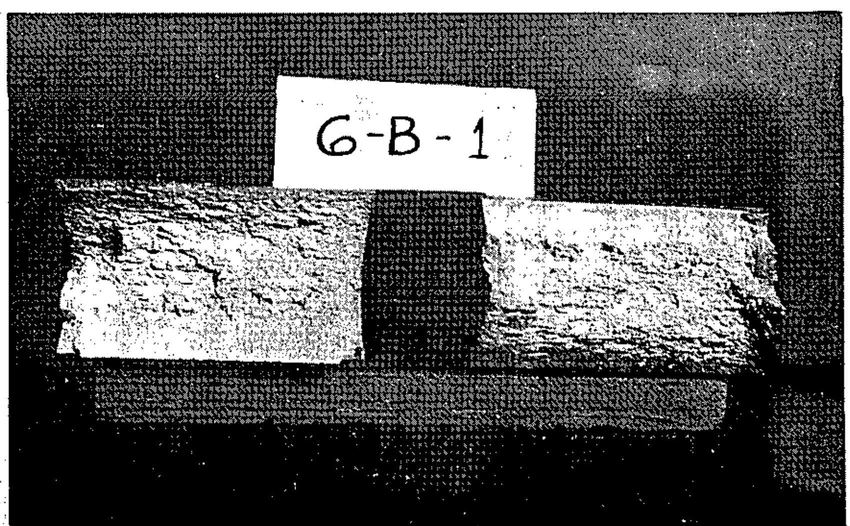
Face view

Side view

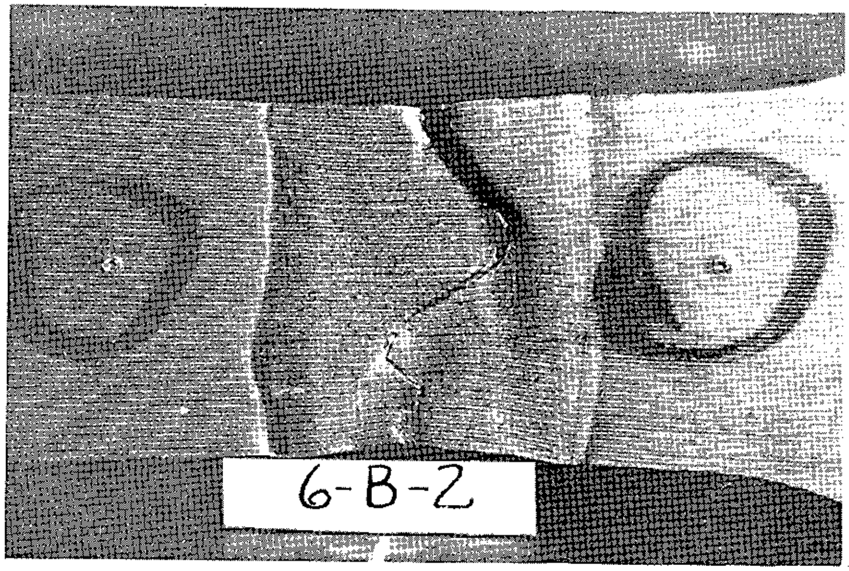
2" strap tensile
test of 1" butt
joint welded using
Airco 352 electrodes

Yield	110,500 psi
Ultimate	116,300 psi
2" elongation	18 %
Red Area	15%

Failure in weld metal
and heat affected
zone



End view

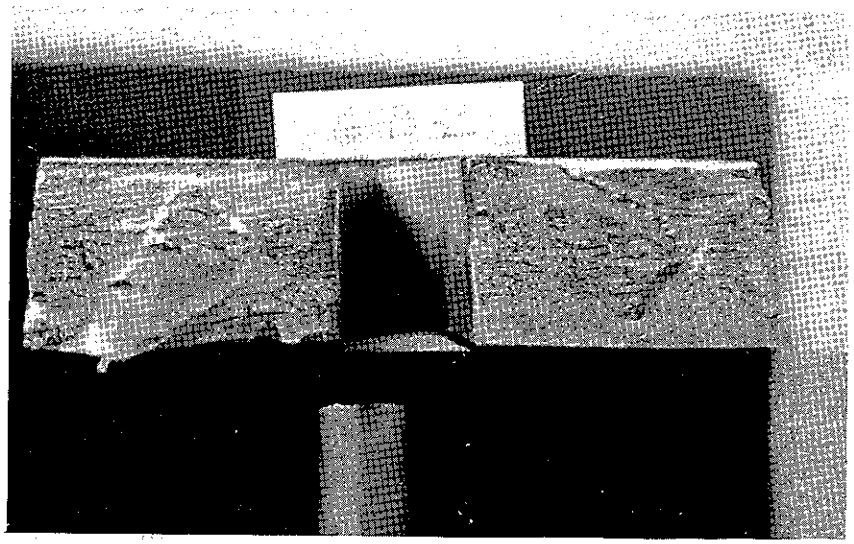


Face view

2" strap tensile test on 1" butt joint welded
using Airco 352 electrodes

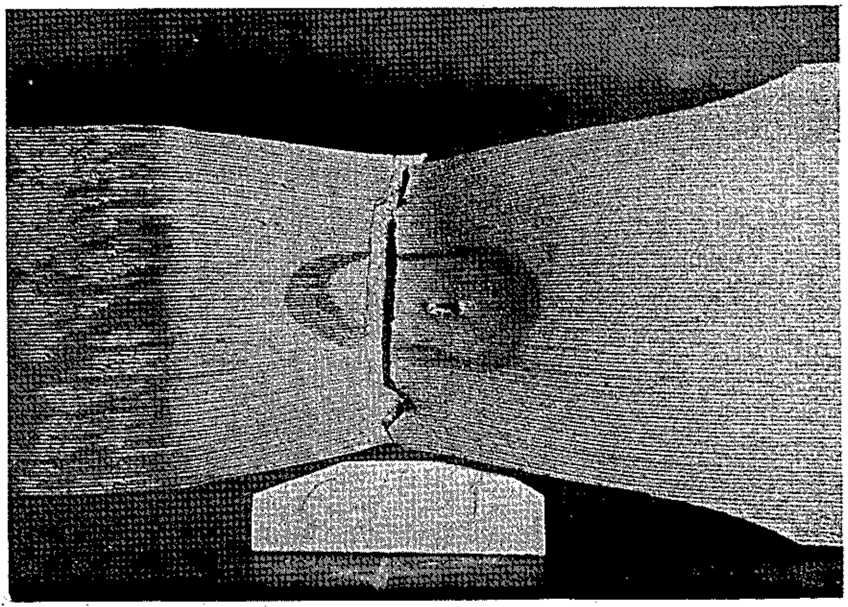
Yield	110,200 psi
Ultimate	124,600 psi
2" elongation	17 %
Red Area	16%

Failure in weld metal



End view
Note fisheye voids and numerous extensive inclusions

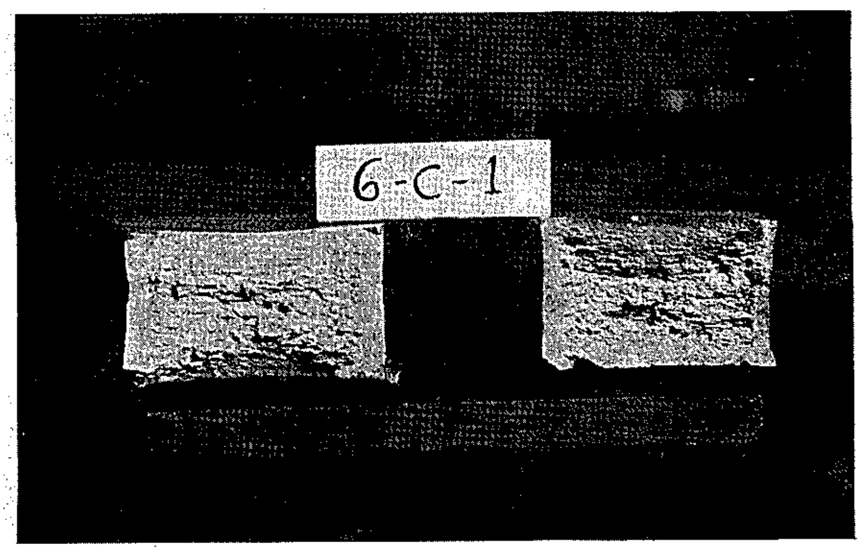
Exhibit 96



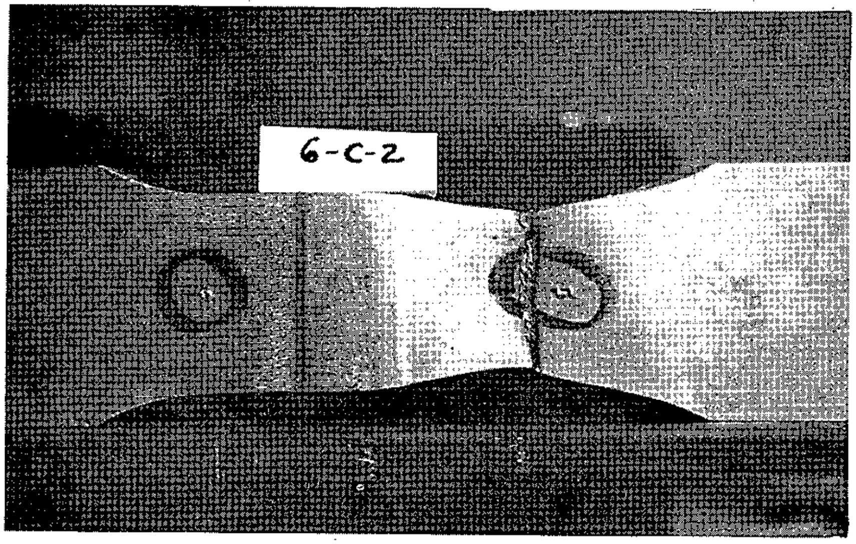
Face view

2" strap tensile test on 1 1/2" butt joint
manually welded using the Airco 352 electrodes
Yield 85,800 psi
Ultimate 95,600 psi
2" elongation 25 %
Red Area 48 %

Failure in parent metal



End view

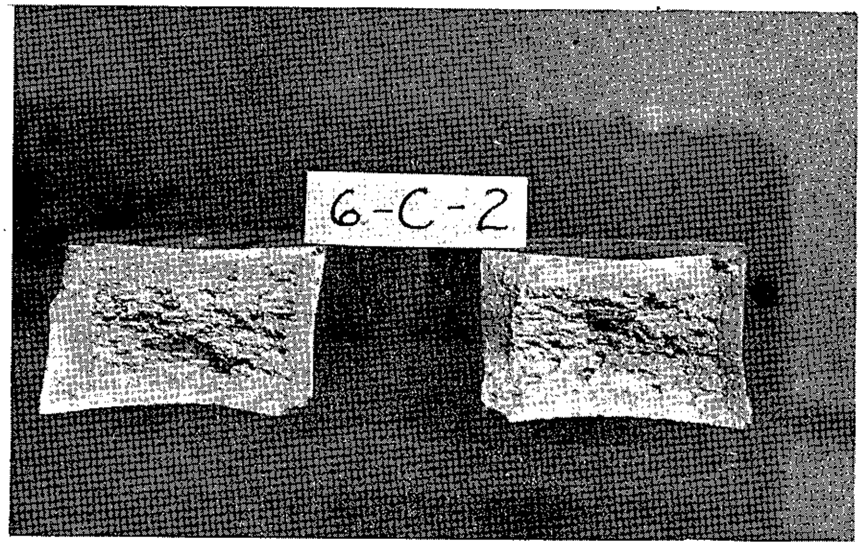


Face view

2" strap tensile test of 1 1/2" butt joint welded using the manual Airco 352 low hydrogen electrodes

Yield	87,300 psi
Ultimate	98,700 psi
2" elongation	26 %
Red Area	46 %

Failure in parent metal



End view

VIII APPENDIX

SECTION E

SUMMARY OF BEND TESTS

OF

TRANSVERSE BUTT WELDS

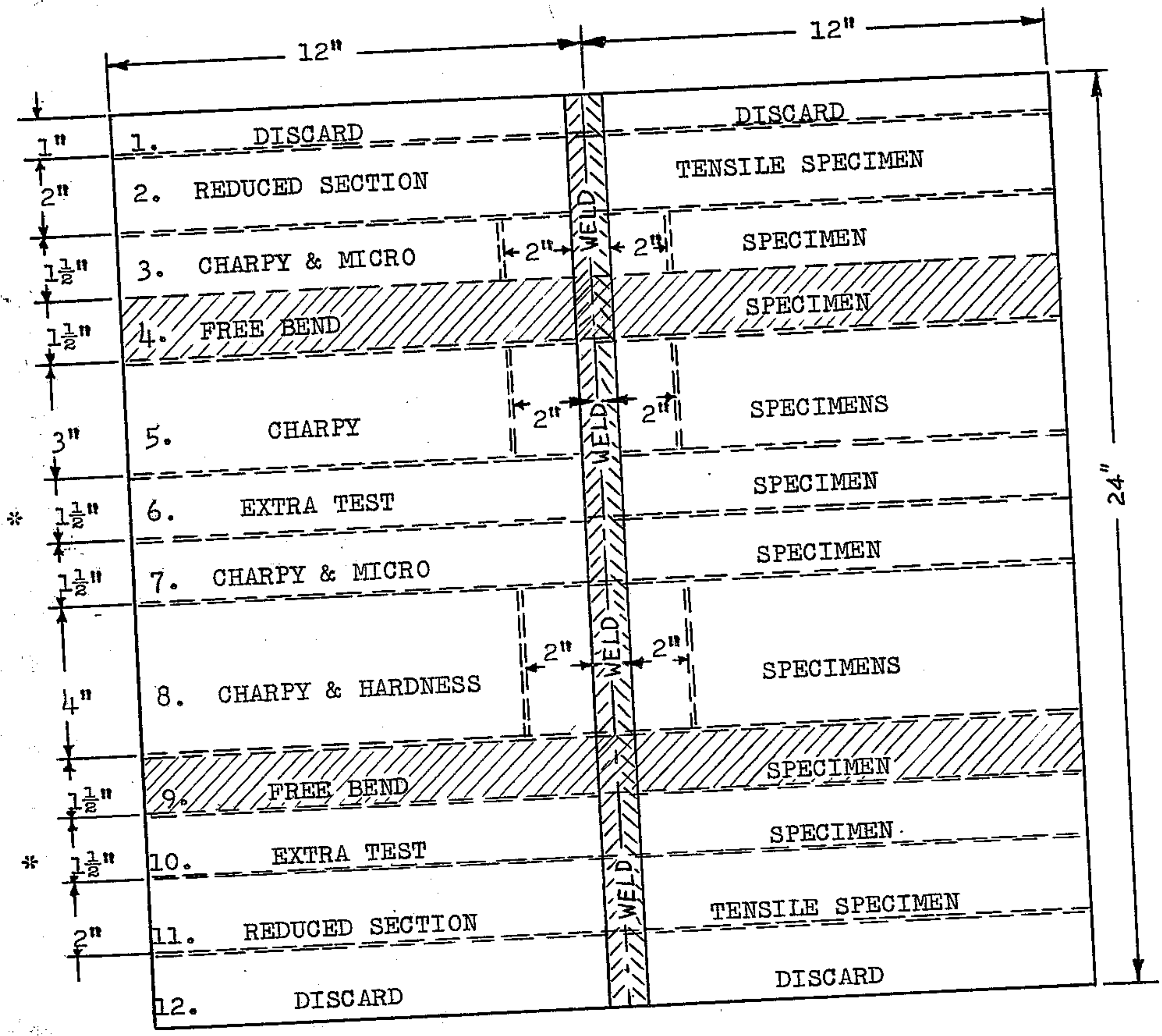
WITH

PHOTOGRAPHS

Exhibit 98

PLAN FOLLOWED IN CUTTING SPECIMENS

From $\frac{1}{2}$" CARILLOY T-1 STEEL TEST PLATES



* Extra Test Specimens for Proof Testing.

PLAN FOLLOWED IN CUTTING SPECIMENS

From 1" and 1½" Carilloy T-1 Steel Test Plates

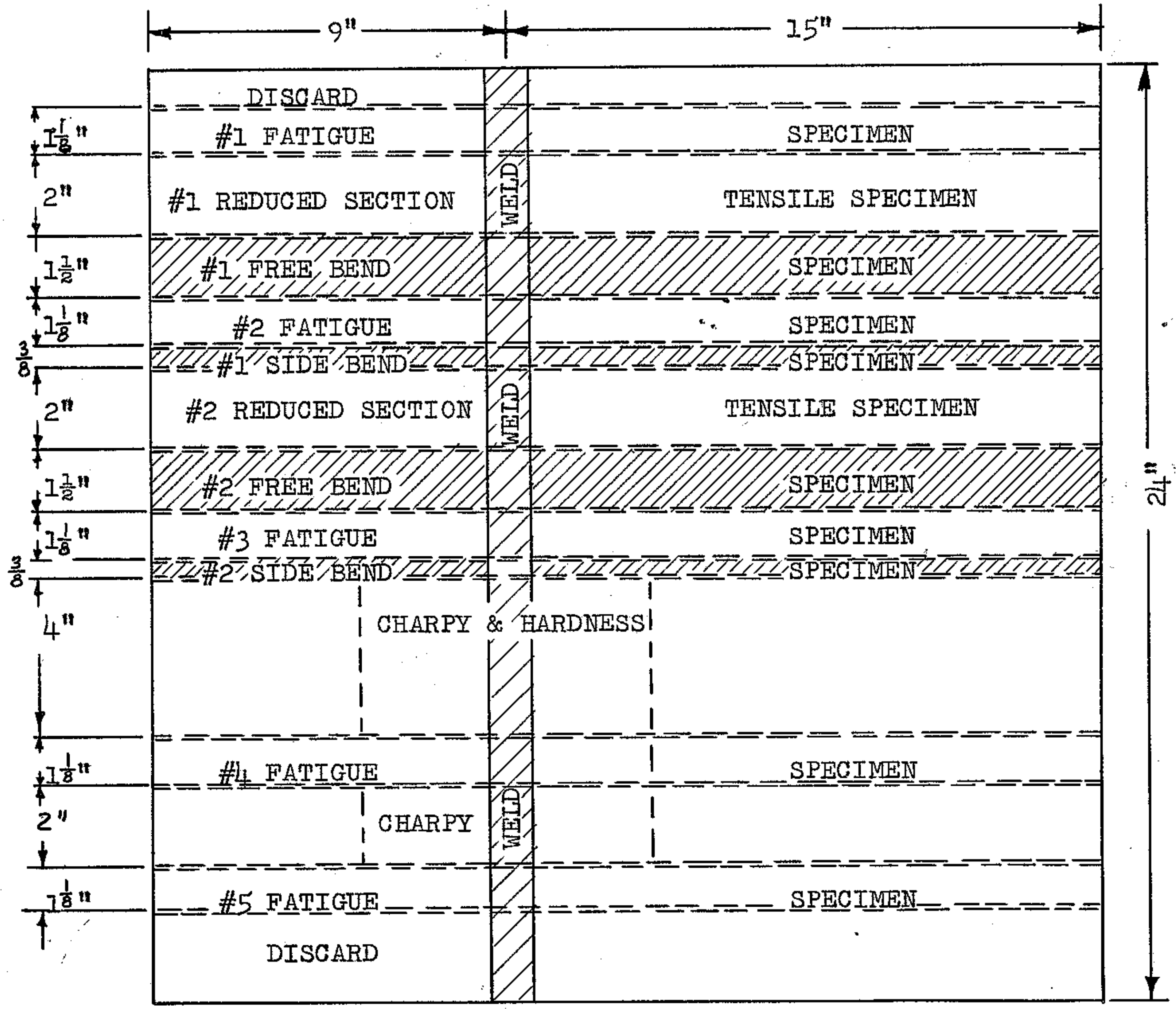
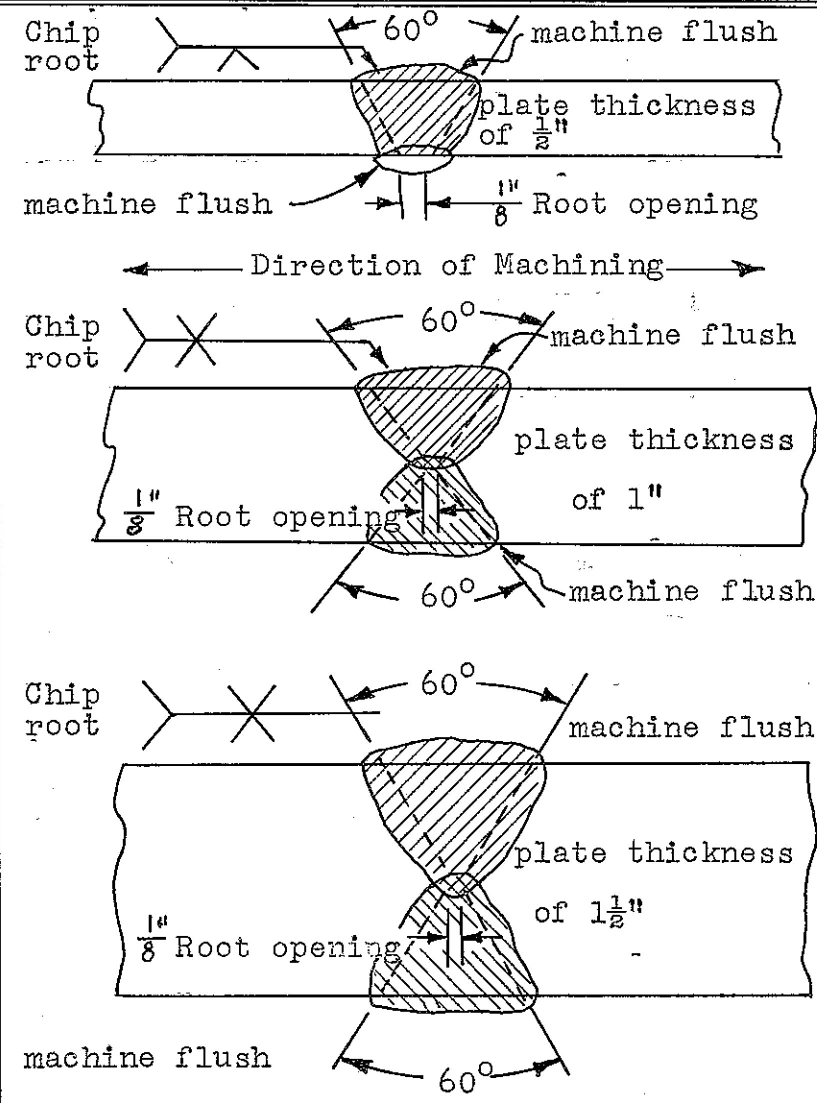


Exhibit 100

TRANSVERSE BUTT WELDED - FREE BEND TEST SPECIMENS

Spec. #	Electrode Used	Welding Process	Elong. %	Location of Fracture	Plate Thickness	Heat #	Typical Detail of weld joint
2-A-1	(E-11016) (Tentative)	A.O.Smith SW91 Manual	38.5%	Weld Metal	$\frac{1}{2}$"		
2-A-2	"	"	43.7%	Weld Metal	$\frac{1}{2}$"		
2-B-1	"	"	25.6%	H.A.Z.-P.M.	1"		
2-B-2	"	"	26.9%	H.A.Z.-P.M.	1"		
2-C-1	"	"	45.3%	H.A.Z.-P.M.	$1\frac{1}{2}$"		
2-C-2	"	"	78.6%	H.A.Z.-P.M.	$1\frac{1}{2}$"		
3-A-1	E-10016	Airco 353 Manual	29.7%	H.A.Z.-P.M.	$\frac{1}{2}$"		
3-A-2	"	"	37.9%	H.A.Z.-P.M.	$\frac{1}{2}$"		
3-B-1	"	"	44.1%	Weld Metal	1"		
3-B-2	"	"	44.0%	H.A.Z.-P.M.	1"		
3-C-1	"	"	32.8%	H.A.Z.-P.M.	$1\frac{1}{2}$"		
3-C-2	"	"	44.0%	H.A.Z.-P.M.	$1\frac{1}{2}$"		

TRANSVERSE BUTT WELDED - FREE BEND TEST SPECIMENS

Spec. #	Electrode Used	Welding Process	Elong. %	Location of Fracture	Plate Thick-ness	Heat #
4-A-1	Oxweld 866-1/8"	Unionmelt #80 Flux	41.3%	No Fracture	½"	
4-A-2	"	"	48.0%	No Fracture	½"	
4-B-1	"	"	39.3%	W.M.-H.A.Z.	1"	
4-B-2	"	"	43.8%	Weld Metal	1"	
4-C-1	"	"	49.3%	Weld Metal	1½"	
4-C-2	"	"	45.3%	Weld Metal	1½"	
5-A-1	A632	Aircomatic Argon 2 gas shield	59.5%	Weld Metal	½"	
5-A-2	"	"	25.0%	H.A.Z.-P.M.	½"	
5-B-1	"	"	28.8%	H.A.Z.-P.M.	1"	
5-B-2	"	"	38.2%	H.A.Z.-P.M.	1"	
5-C-1	"	"	25.6%	H.A.Z.-P.M.	1½"	
5-C-2	"	"	38.9%	No Fracture	1½"	

Typical Detail of weld joint

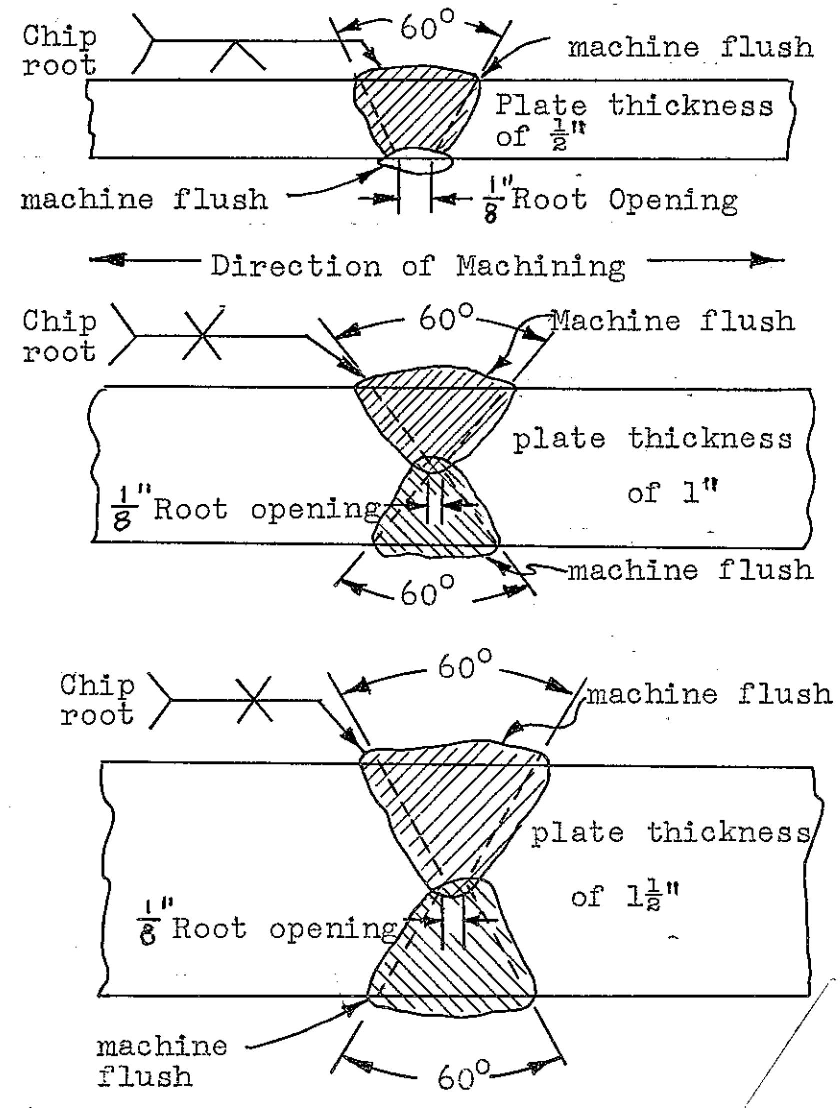
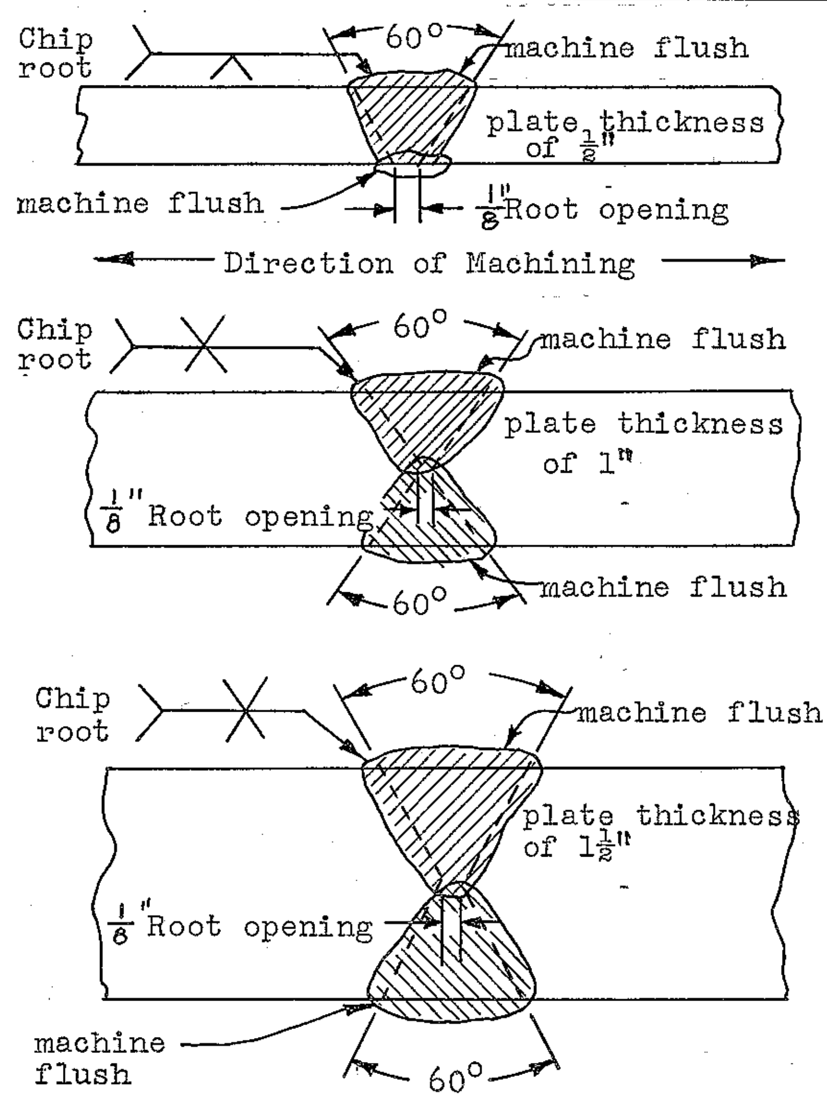
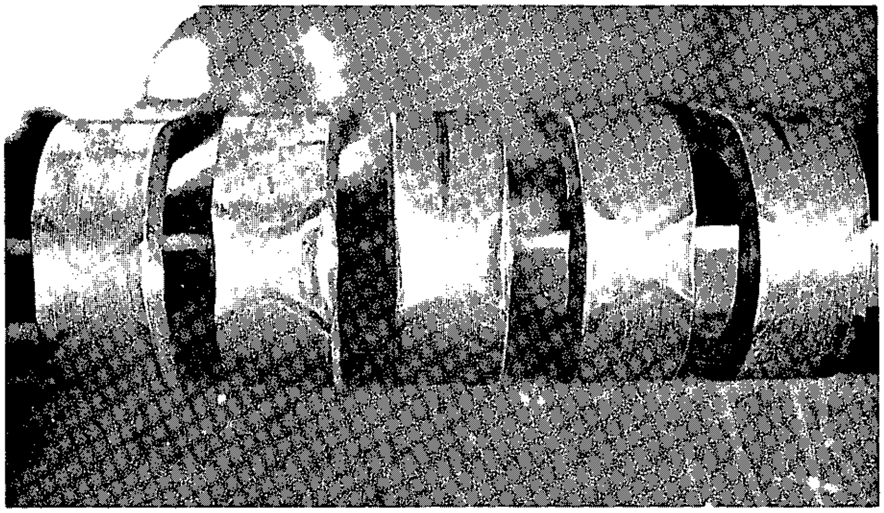


Exhibit 102

TRANSVERSE BUTT WELDED - FREE BEND TEST SPECIMENS

Spec. #	Electrode Used	Welding Process	Elong. %	Location of Fracture	Plate Thick-ness	Heat #	Typical Detail of weld joint
6-A-1	E-12015	Airco 352 Manual	25.0%	H.A.Z.-P.M.	½"		
6-A-2	"	"	23.9%	H.A.Z.-P.M.	½"		
6-B-1	"	"	15.3%	H.A.Z.-P.M.	1"		
6-B-2	"	"	13.3%	H.A.Z.-P.M.	1"		
6-C-1	"	"	16.4%	H.A.Z.-P.M.	1½"		
6-C-2	"	"	16.7%	H.A.Z.-P.M.	1½"		

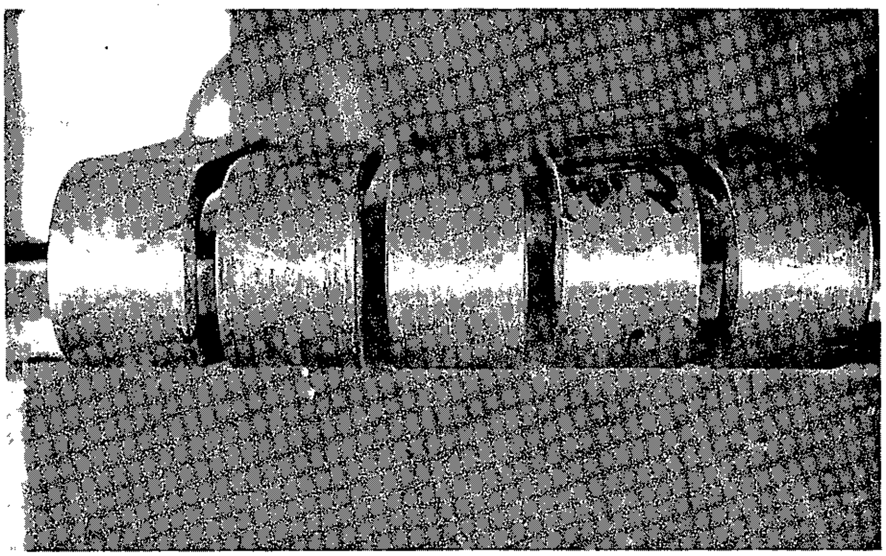




2 3 4 5 6

Guided side bend tests of 1" and 1 1/2" Butt joints welded as follows:

2 A.O.Smith process using SW91 electrodes
3 Airco process using 353 electrodes
4 Unionmelt process using #80 flux and Oxweld 866 electrode wire
5 Aircomatic process using #2 gas shield and A632 electrode wire
6 Airco process using 352 electrodes



6 5 4 3 2

MANUAL WELDING

PHOTOGRAPHS

OF

FREE FACE BEND TESTS

ON

BUTT WELDED JOINTS

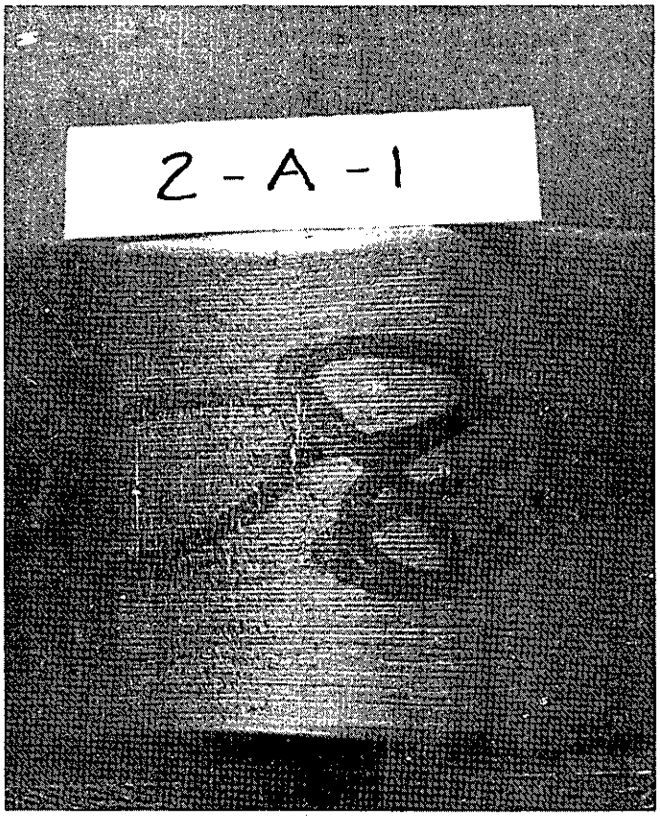
USING

A.O.SMITH

S. W. 91, LOW HYDROGEN ELECTRODES

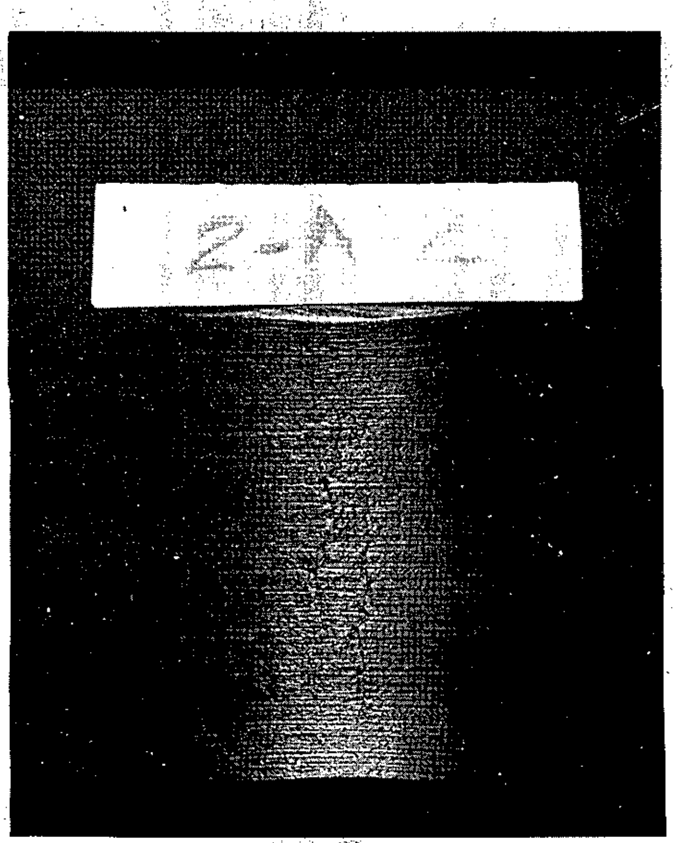
(E-11016 TENTATIVE)

Exhibit 104



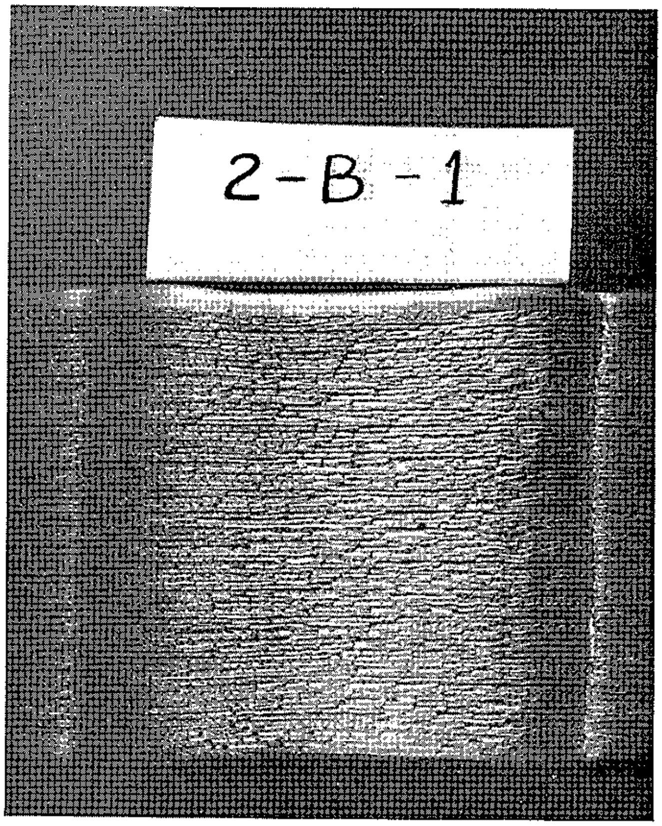
Failure in weld metal face

Elongation 38.5%



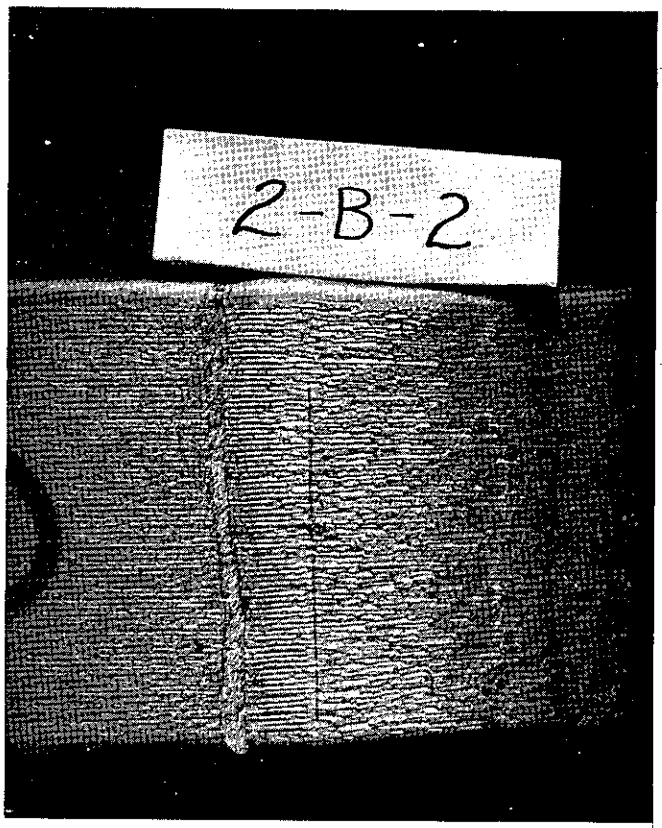
Failure in weld metal face

Elongation 43.7%



Failure in heat affected zone

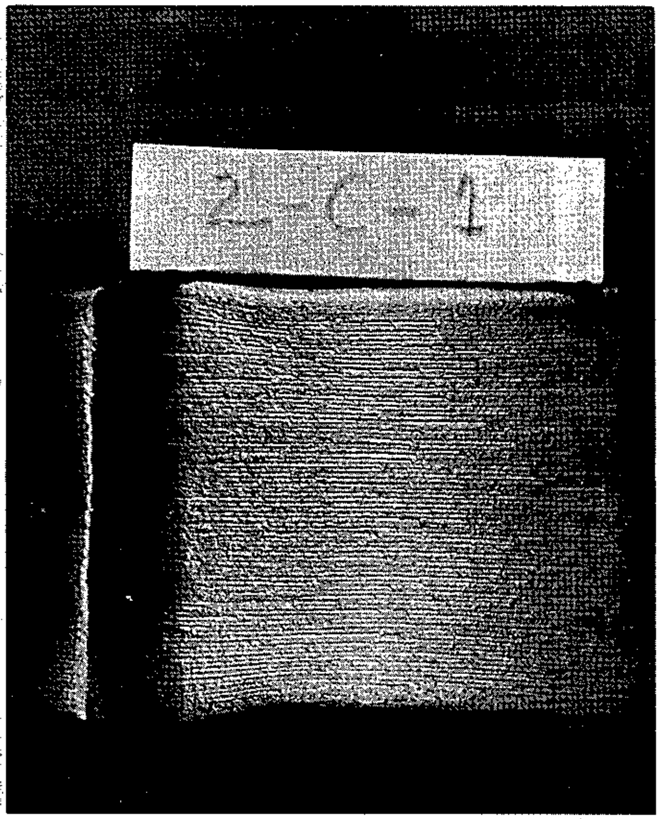
Elongation 25.6%



Failure in heat affected zone

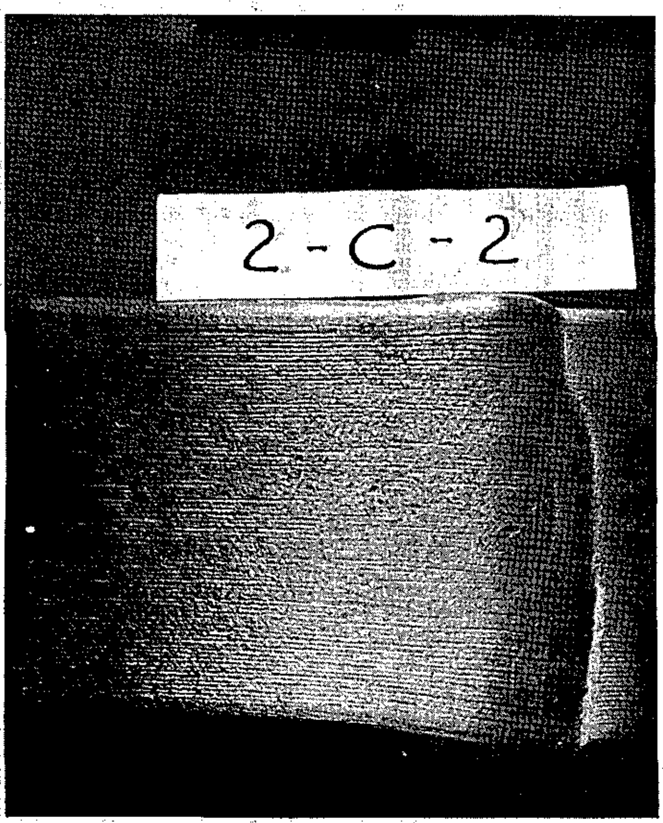
Elongation 26.9%

Exhibit 106



Failure in heat affected zone

Elongation 45.3%



Failure in heat affected zone

Elongation 78.6%

MANUAL WELDING

PHOTOGRAPHS

OF

FREE FACE BEND TESTS

ON

BUTT WELDED JOINTS

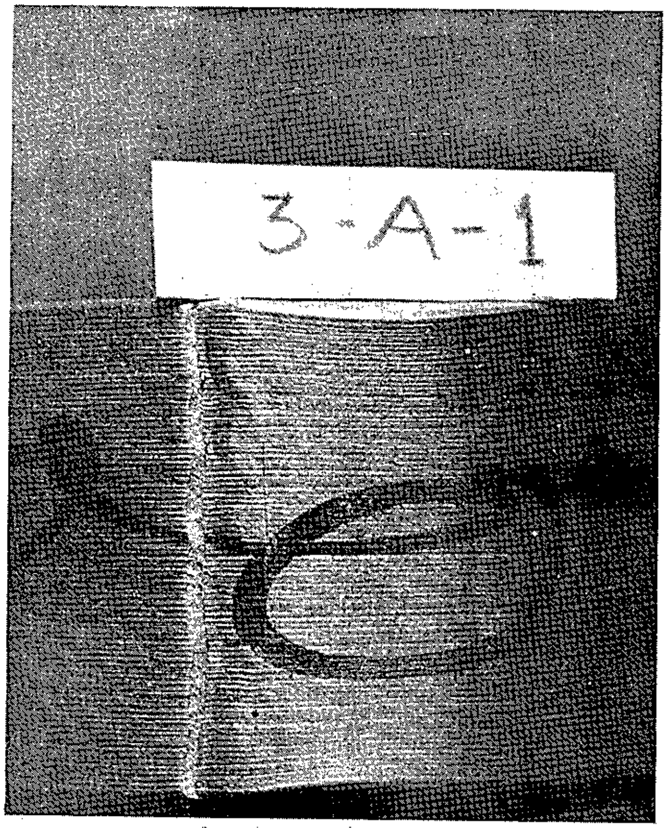
USING

AIRCO

353, LOW HYDROGEN ELECTRODES

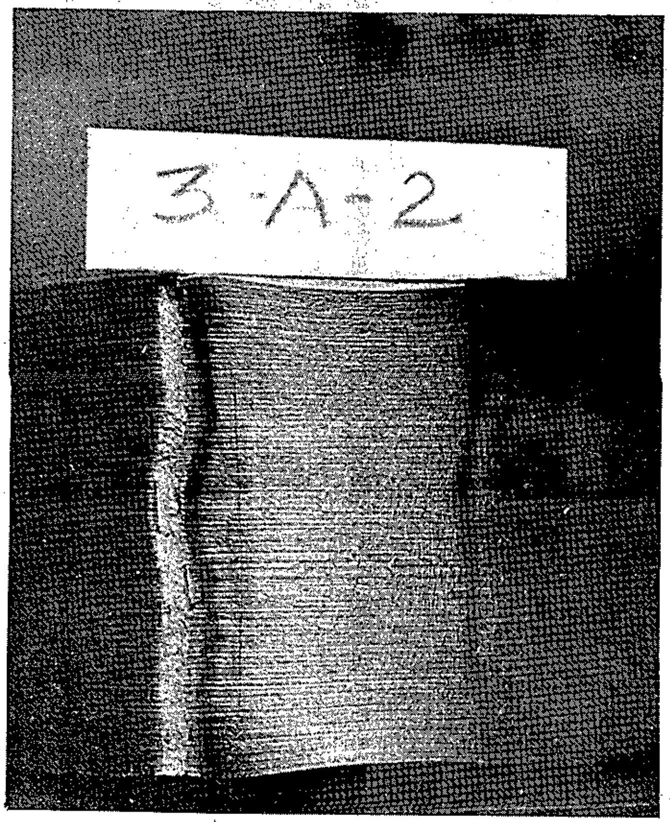
(E-10016)

Exhibit 107



Failure in
heat affected
zone

Elongation 29.7%

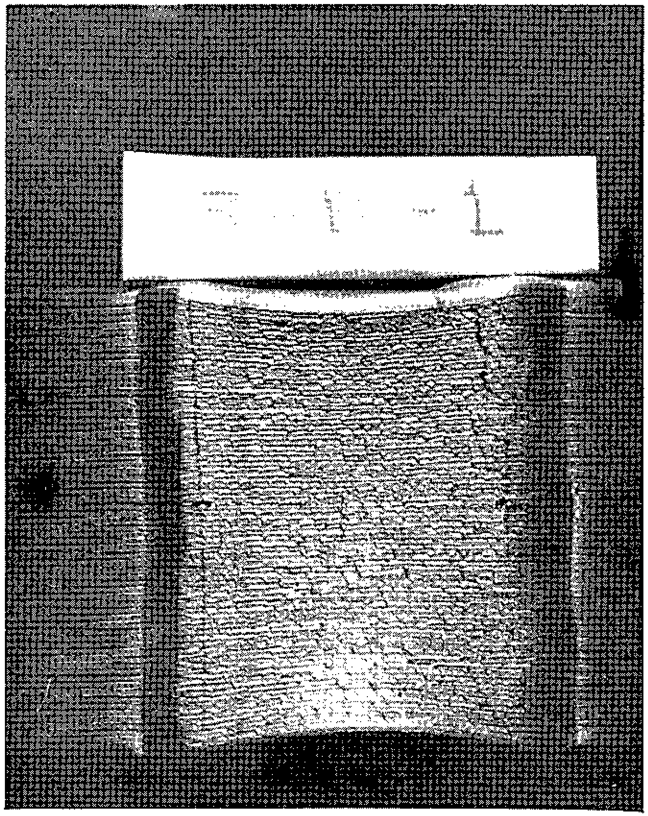


Failure in
heat affected zone

Elongation 37.9%

Failure in
weld metal face

Elongation 44.1%



Failure in weld
metal face and
heat affected
zone

Elongation 44.0%

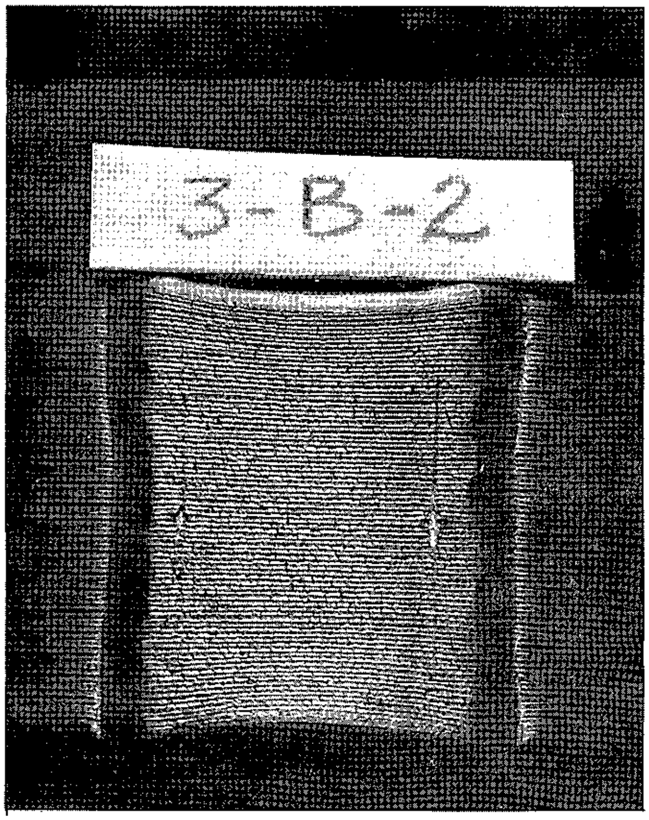
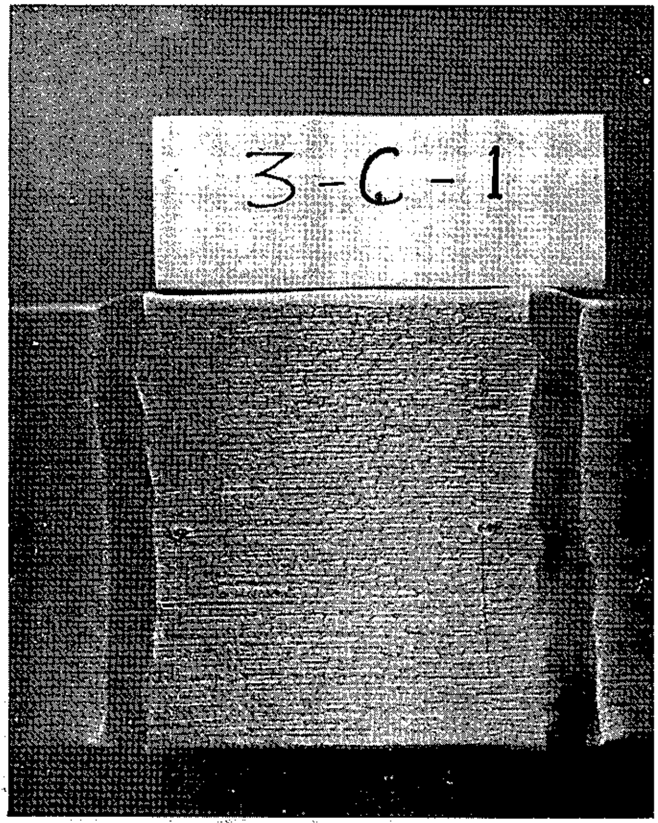
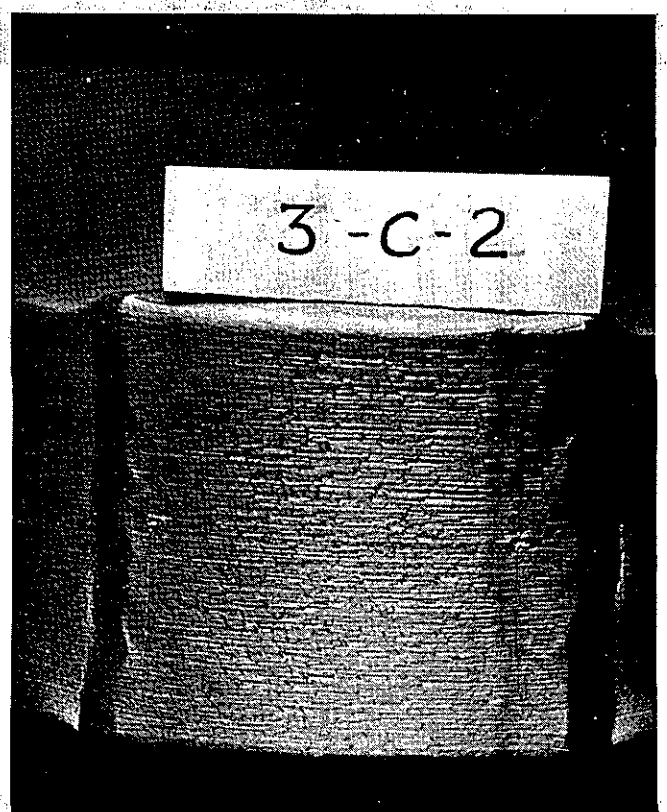


Exhibit 109



Failure in
heat affected zone

Elongation 32.8%



Failure in
heat affected zone

Elongation 44.0%

AUTOMATIC WELDING

PHOTOGRAPHS

OF

FREE FACE BEND TESTS

ON

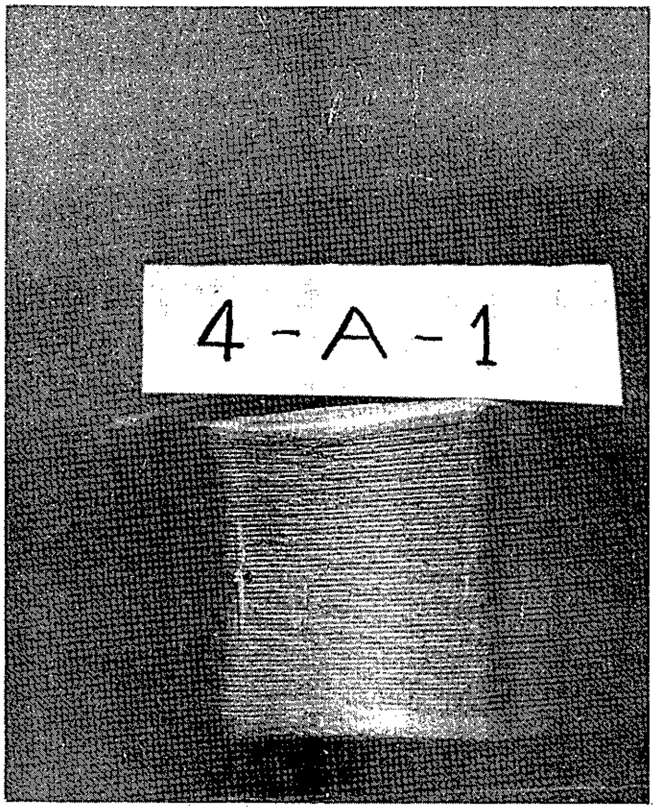
BUTT WELDED JOINTS

USING

UNIONMELT SUBMERGED ARC PROCESS

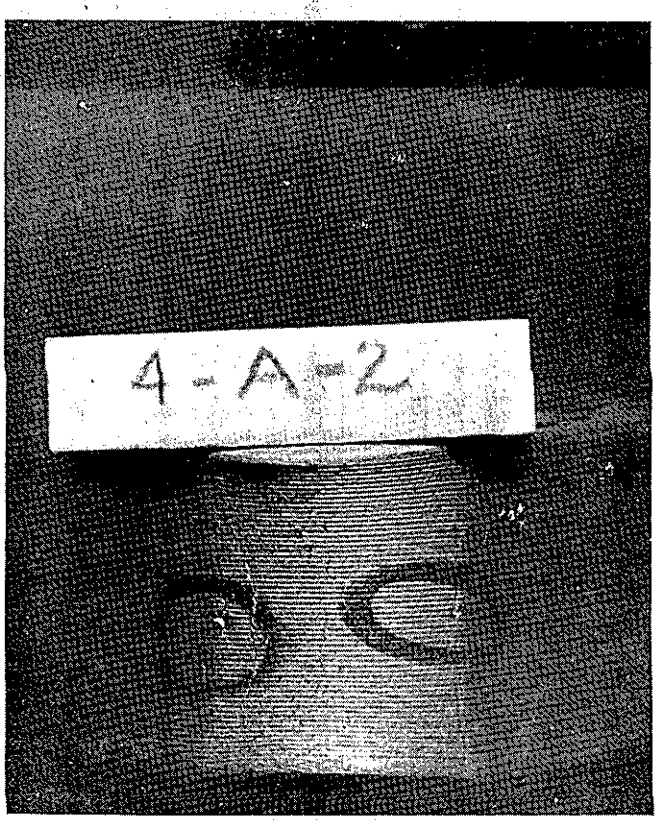
WITH

OXWELD 866 ELECTRODE WIRE AND 80 FLUX



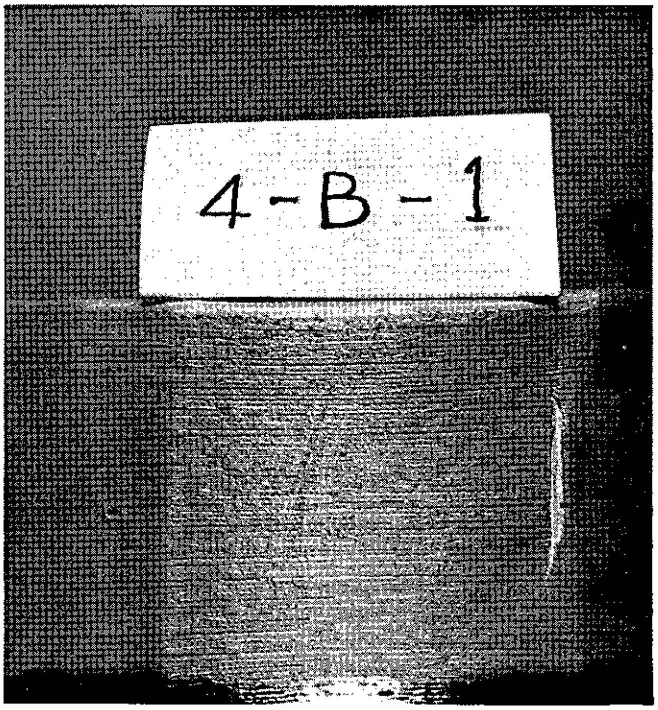
Failure in
weld metal face

Elongation 41.3%



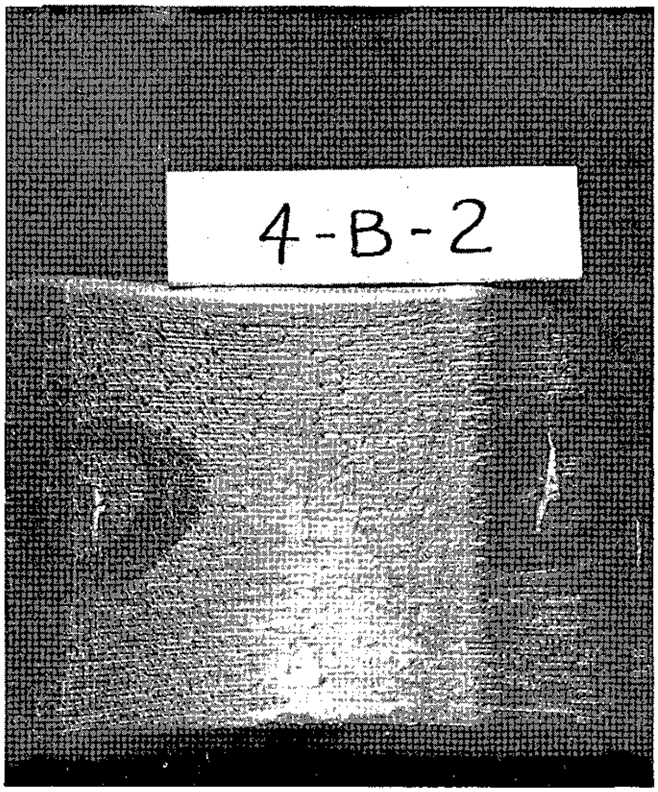
Failure in
weld metal face

Elongation 48%



Failure in
weld metal face

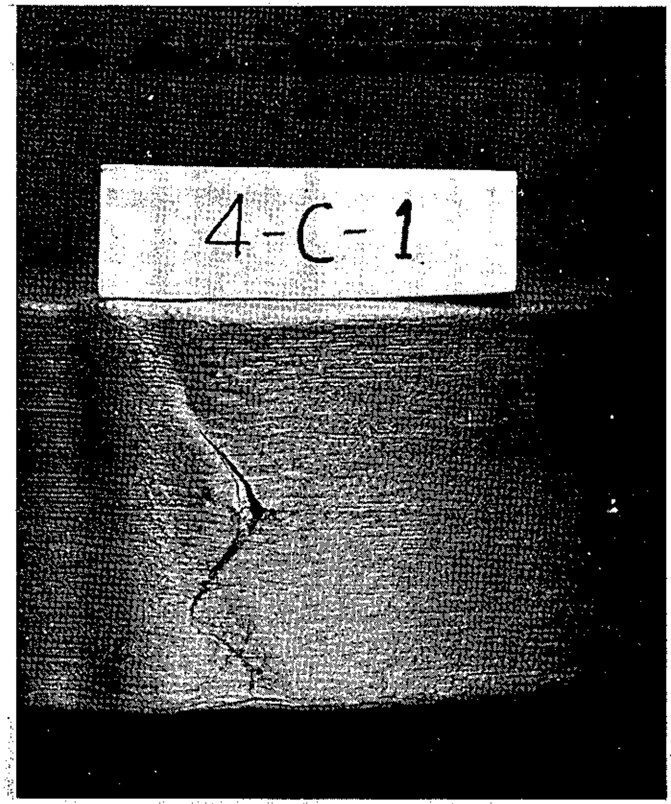
Elongation 39.3%



Failure in
weld metal face

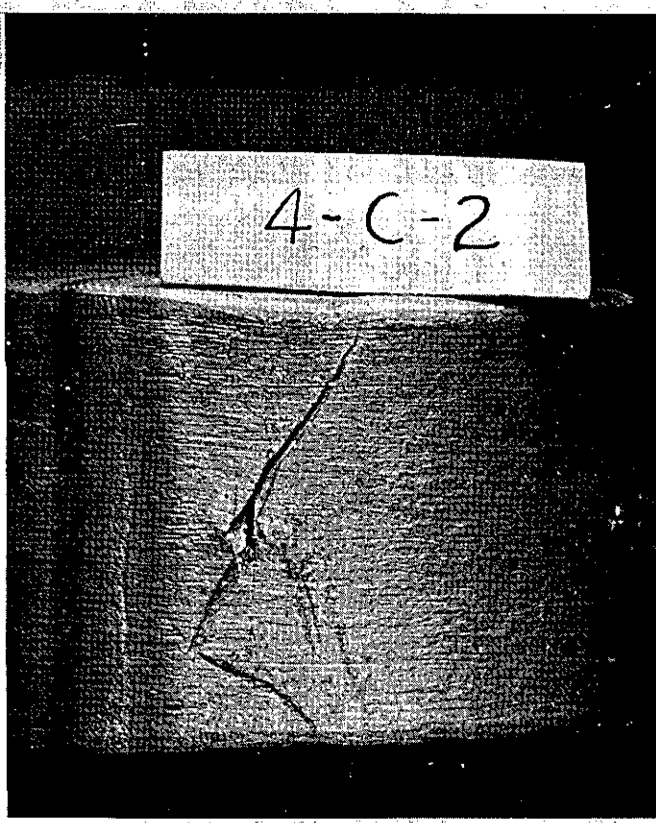
Elongation 43.8%

Exhibit 112



Failure in
weld metal face

Elongation 49.3%



Failure in
weld metal face

Elongation 45.3%

SEMI-AUTOMATIC WELDING

PHOTOGRAPHS

OF

FACE FREE BEND TESTS

OF

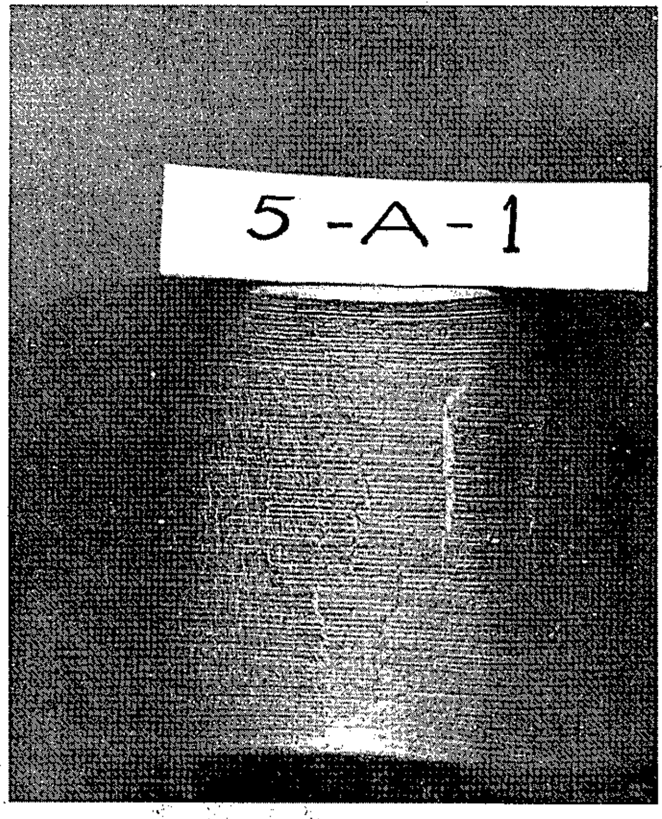
BUTT WELDED JOINTS

USING

AIRCOMATIC INERT GAS SHIELDED ARC PROCESS

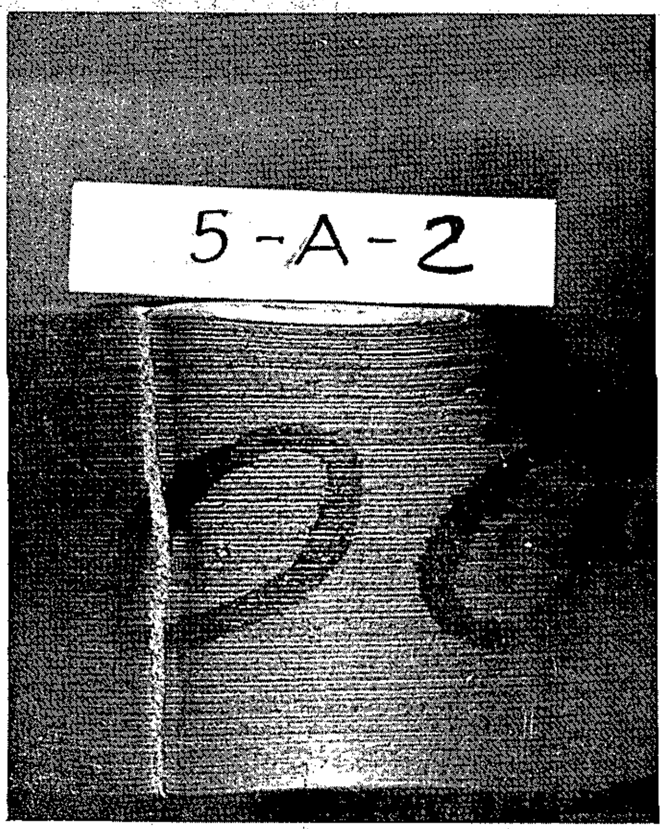
WITH

A632 ELECTRODE WIRE AND A 98%A - 2%O_2 SHIELD



Failure in
weld metal face

Elongation 59.5%

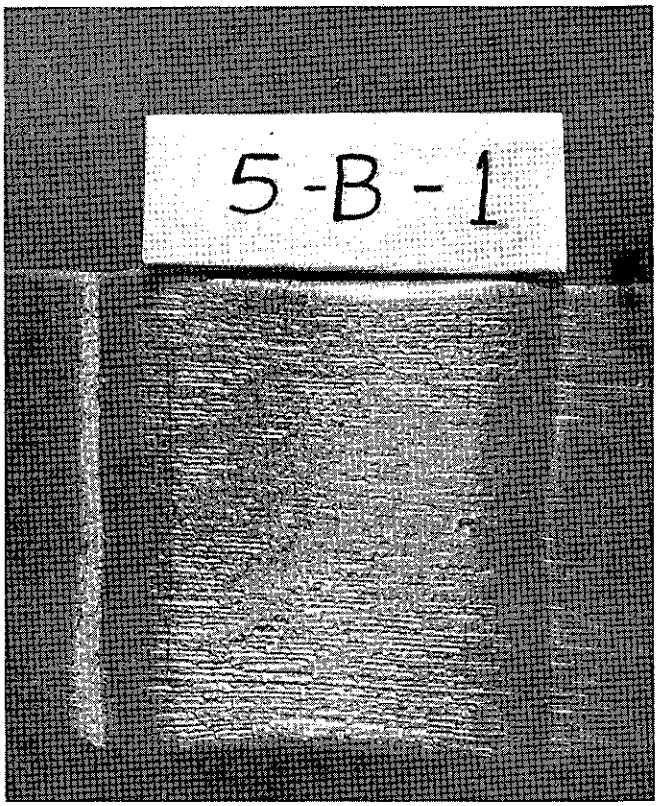


Failure in
heat affected zone

Elongation 25%

Failure in
heat affected zone

Elongation 28.8%



Failure in
heat affected zone

Elongation 38.2%

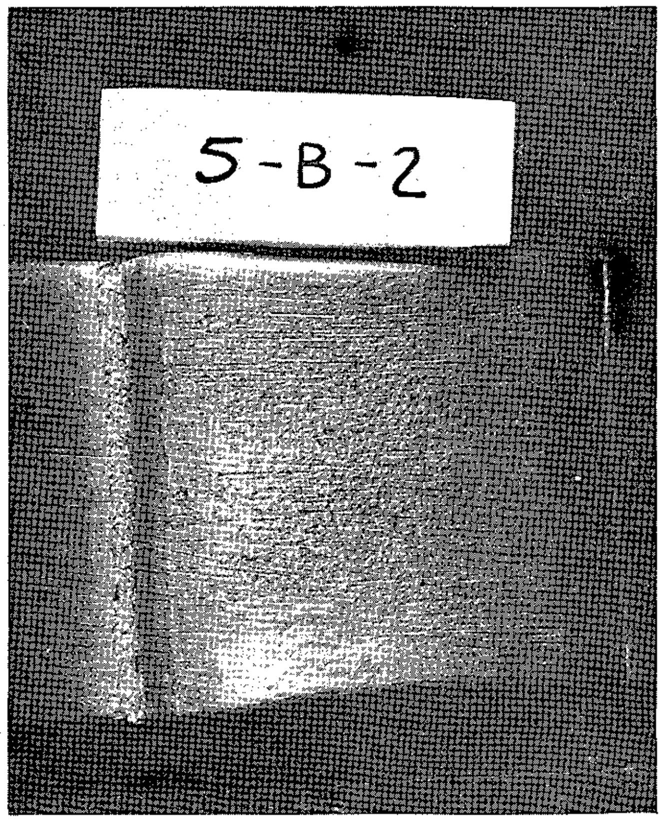
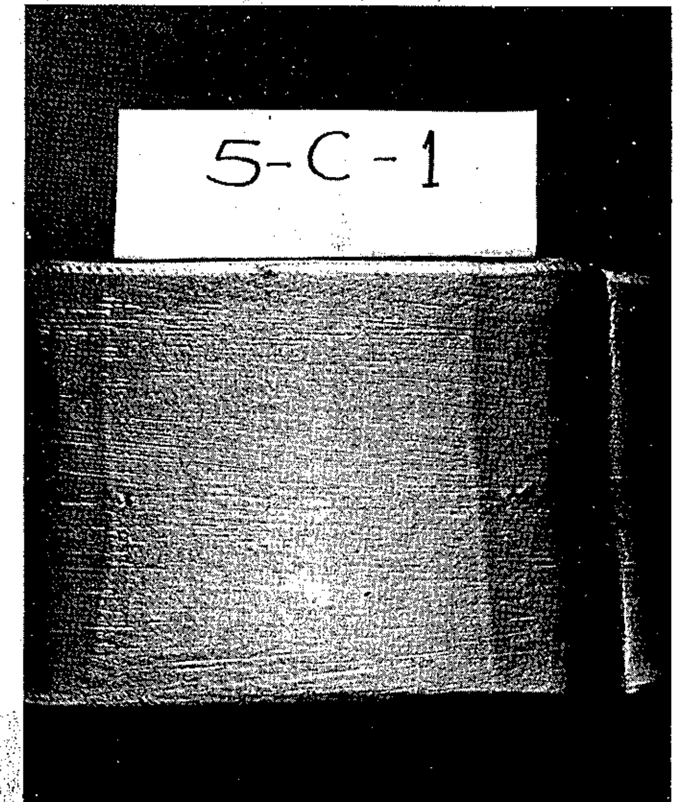
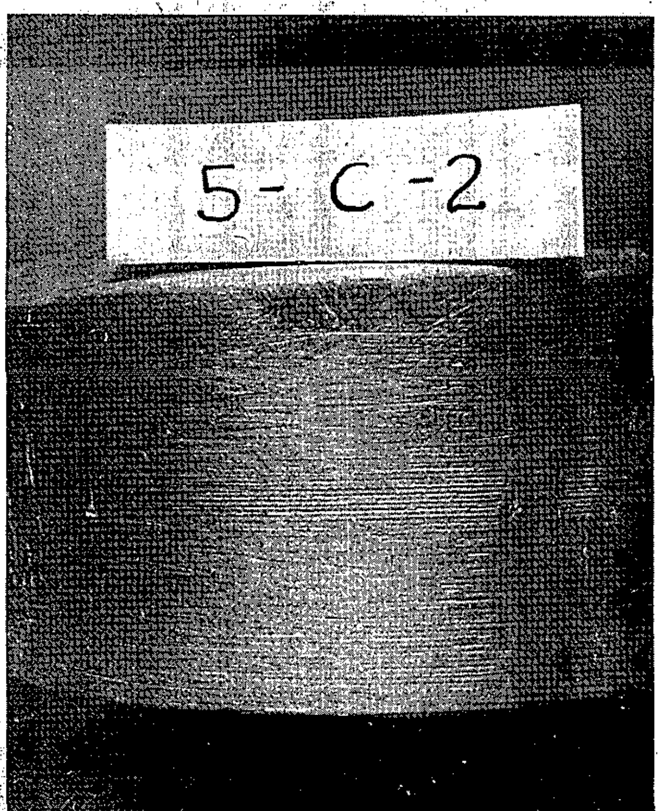


Exhibit 115



Failure in
heat affected zone

Elongation 25.6%



Failure in
parent metal

Elongation 38.9%

MANUAL WELDING

PHOTOGRAPHS

OF

FACE FREE BEND TESTS

ON

BUTT WELDED JOINTS

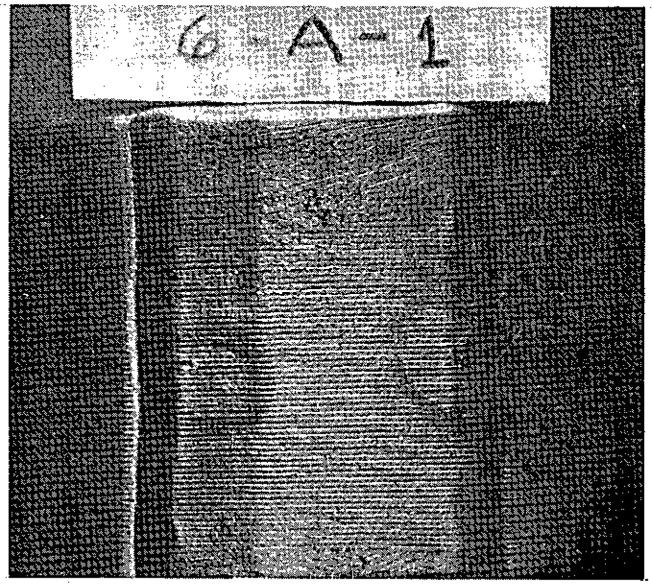
USING

AIRCO

352, LOW HYDROGEN ELECTRODES

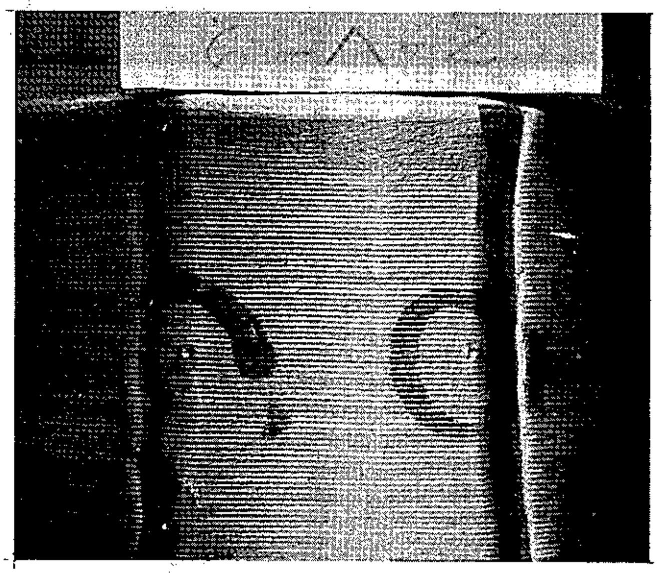
(E-12015)

Exhibit 116



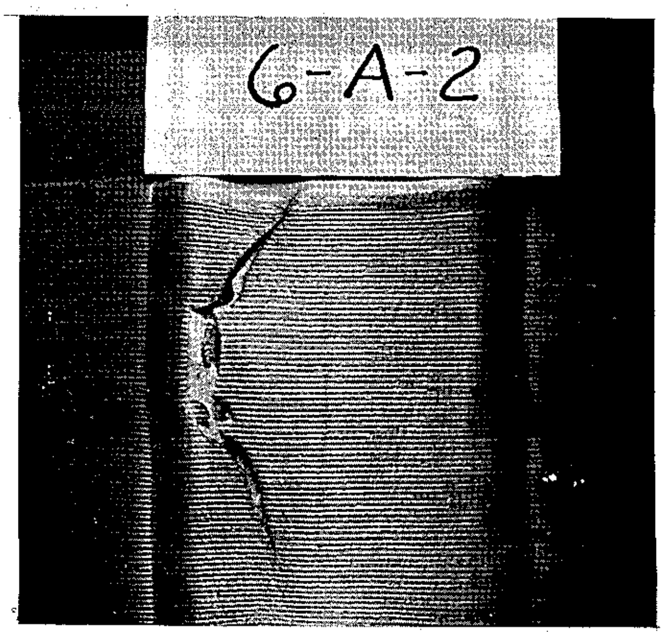
Failure in
heat affected zone

Elongation 25%



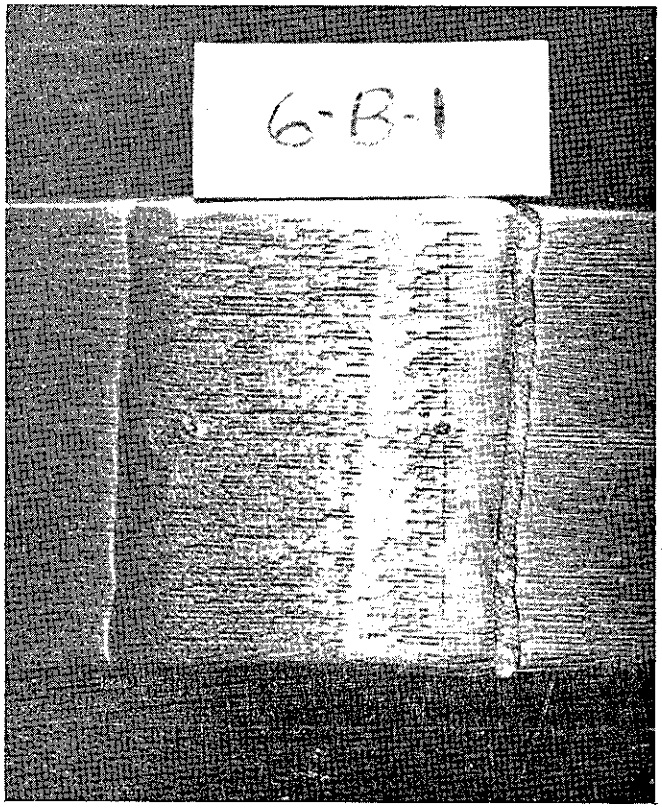
Failure in
heat affected zone

Elongation 23.9%



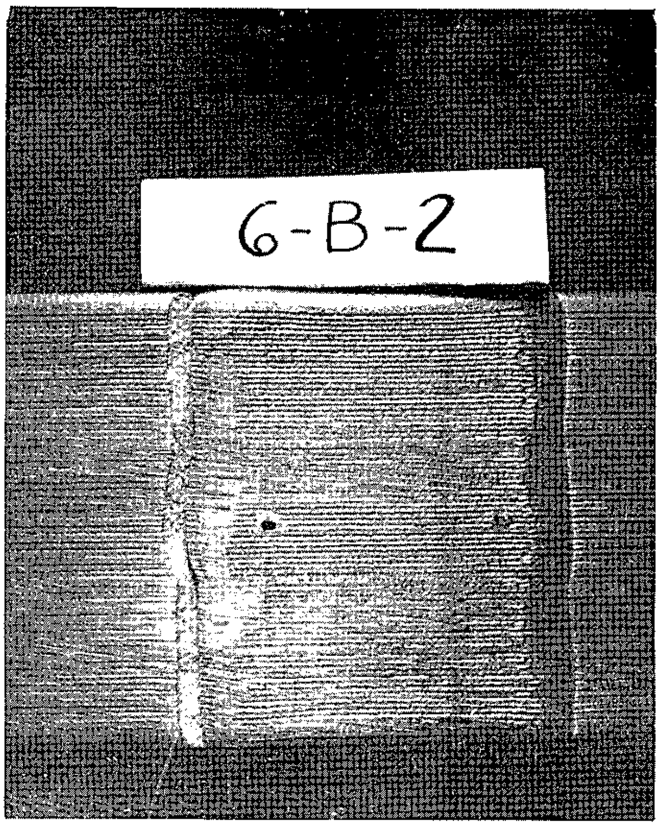
Failure in
Weld metal face

60° bend



Failure in
heat affected zone

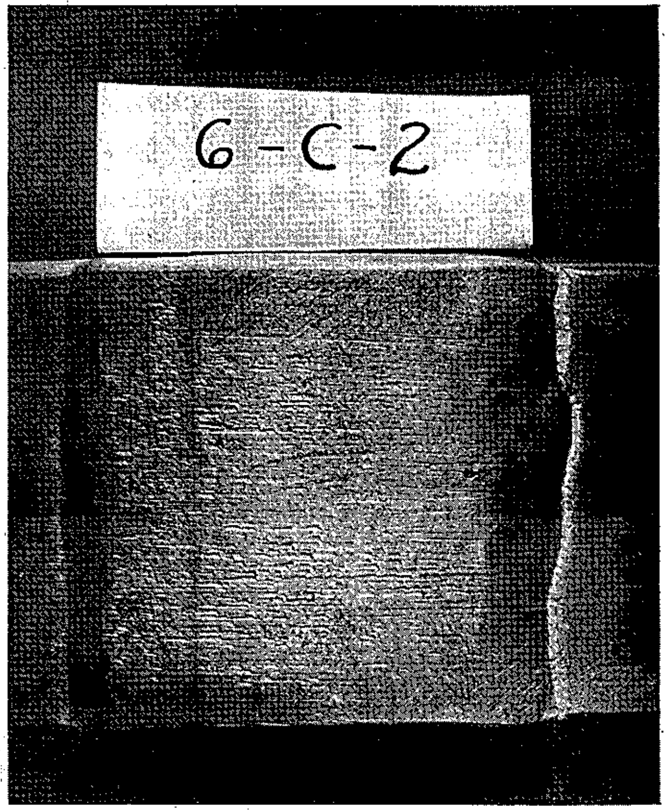
Elongation 15.3%



Failure in
heat affected zone

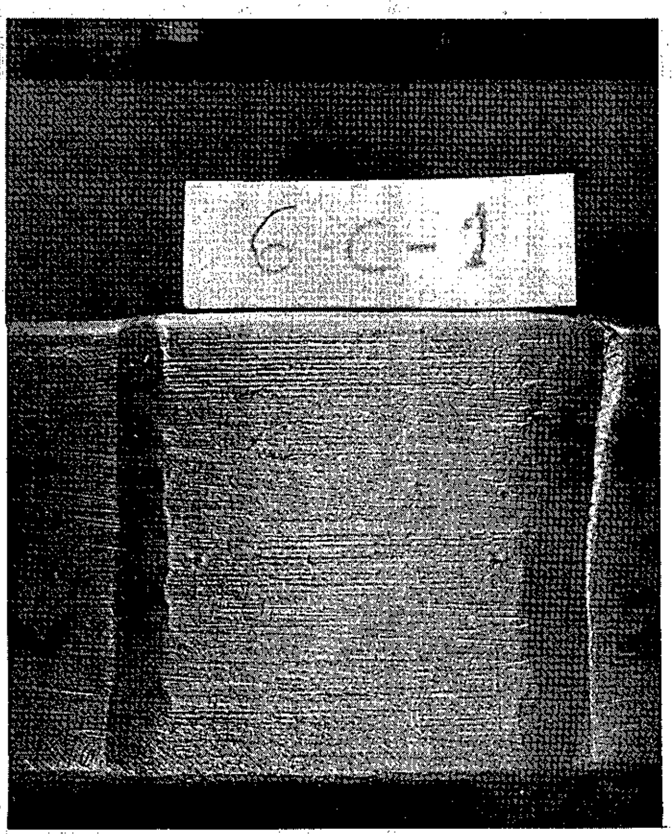
13.3% Elongation

Exhibit 118



Failure in
heat affected zone

Elongation 16.4%



Failure in heat
affected zone

Elongation 16.7%

VIII APPENDIX

SECTION F

FATIGUE DATA

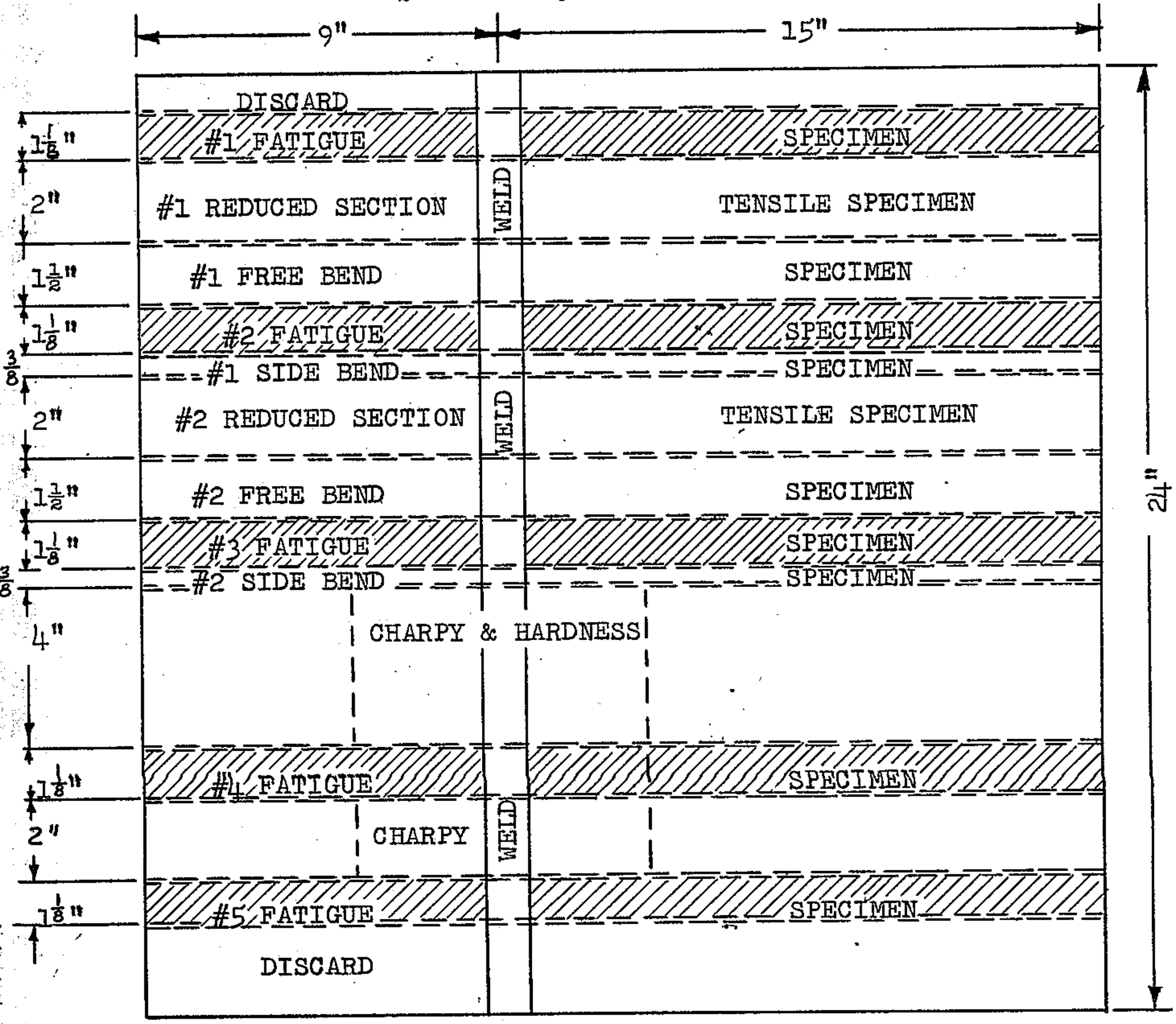
WITH

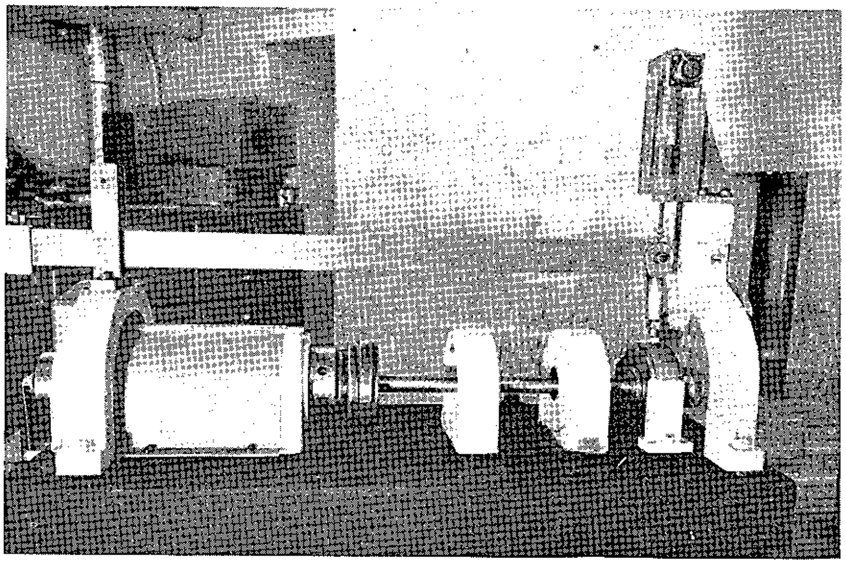
SN DIAGRAMS AND PHOTOGRAPHS

Exhibit 119

PLAN FOLLOWED IN CUTTING SPECIMENS

From 1" and $1\frac{1}{2}$" Carilloy T-1 Steel Test Plates





Fatigue machine with specimen in place showing driving motor, gearbox, table, electronic gear, and extra weights and collet.

See following page for parts and details.

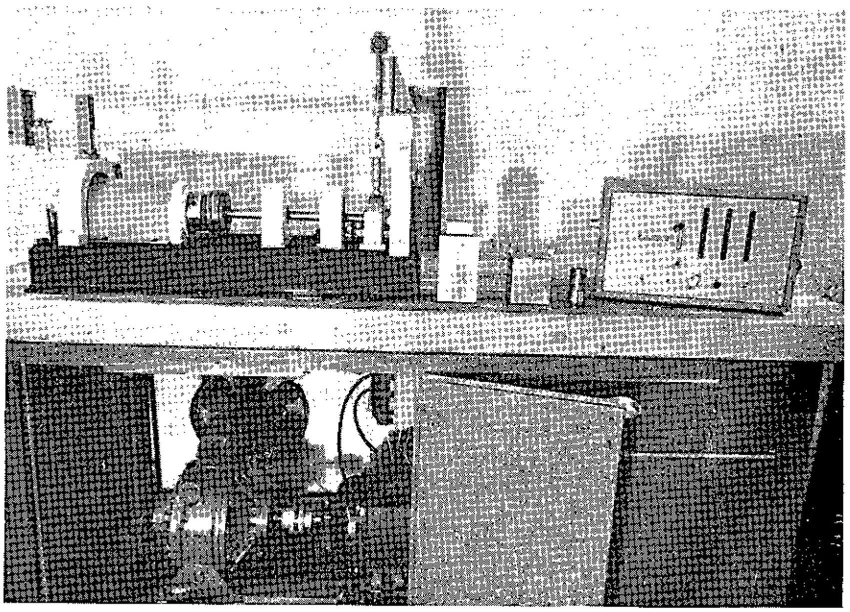
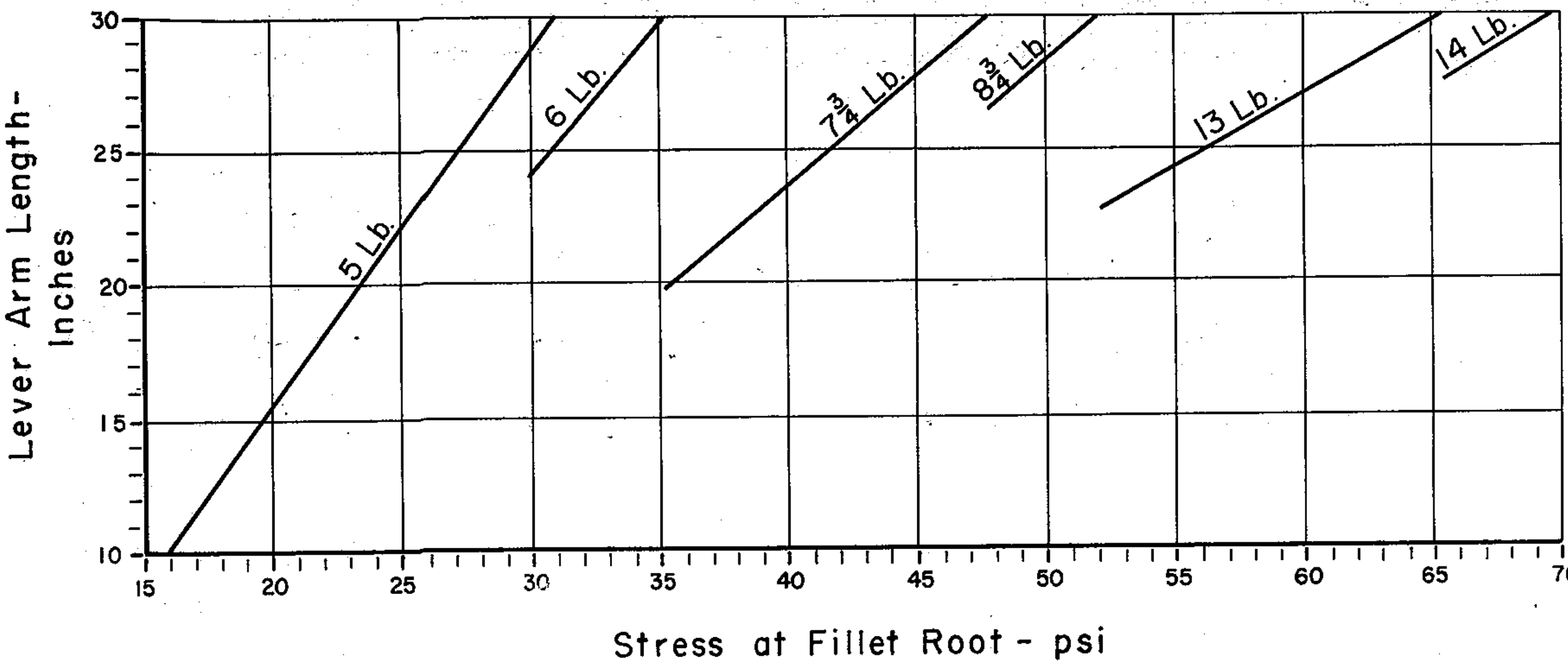
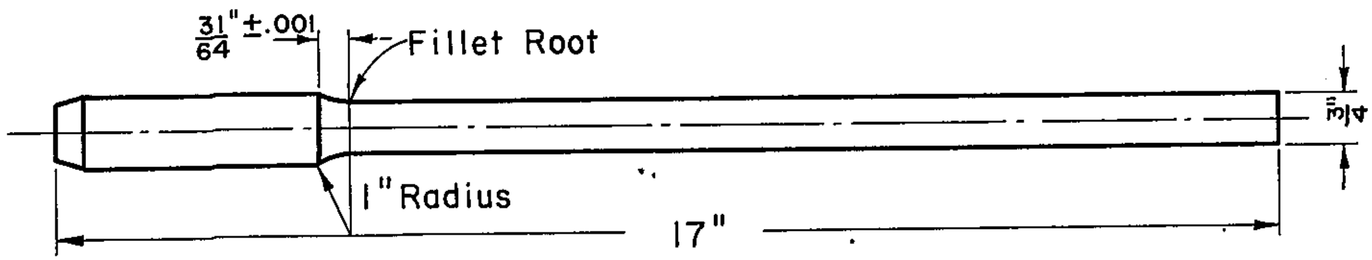


EXHIBIT NO. 121





WEIGHT POSITION CHART

EXHIBIT NO. 122

SINGLE END ROTATING CANTILEVER FATIGUE TESTING MACHINE

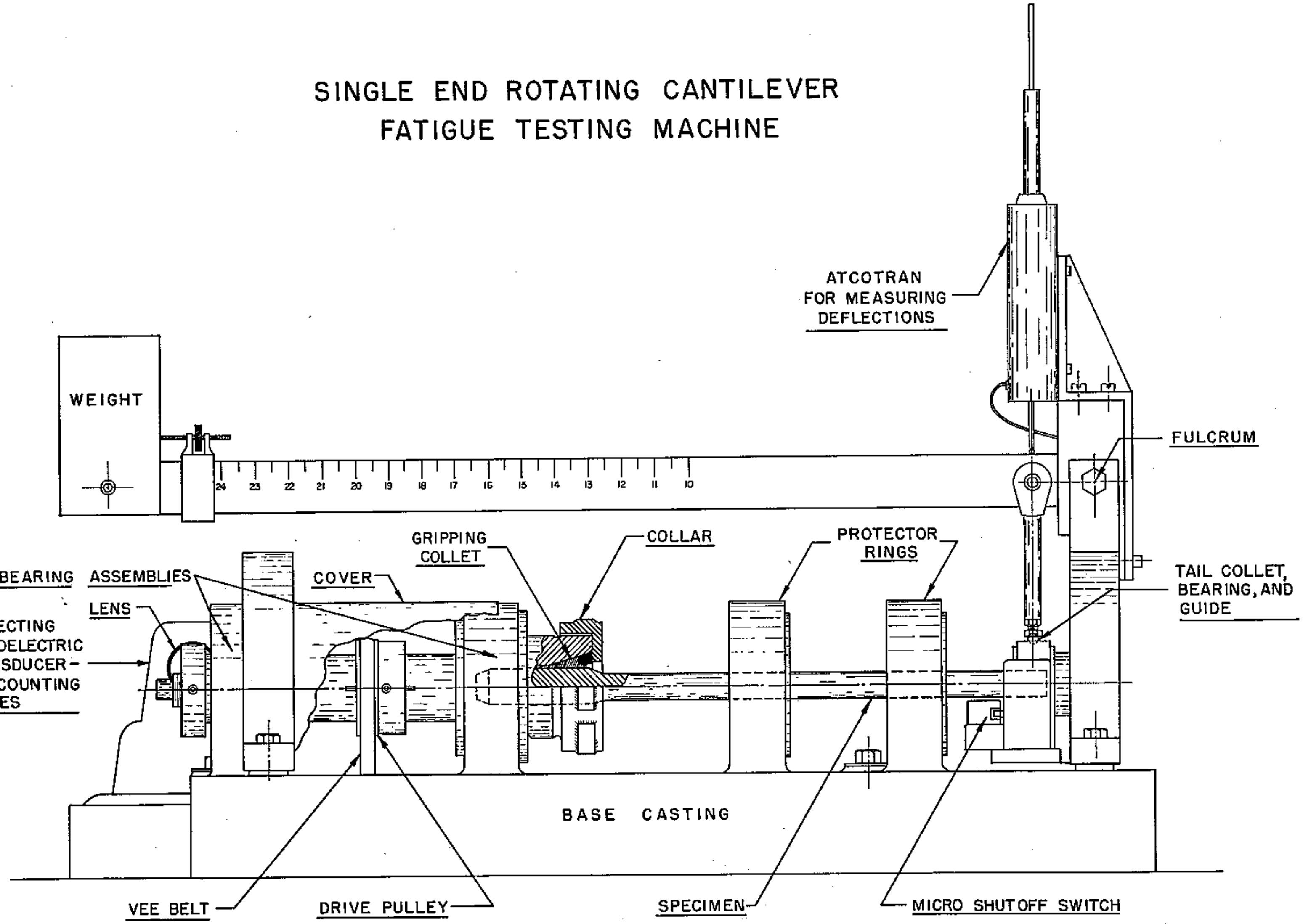
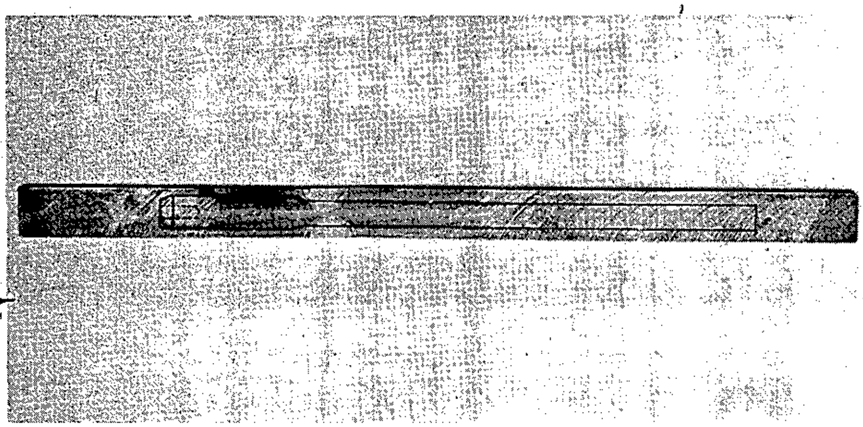
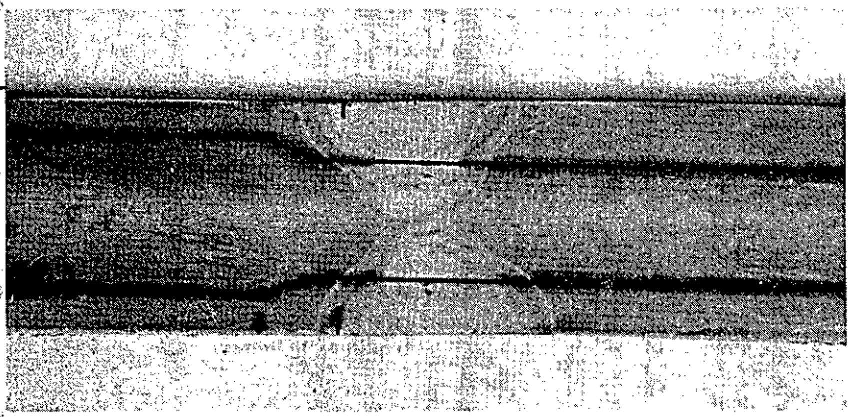


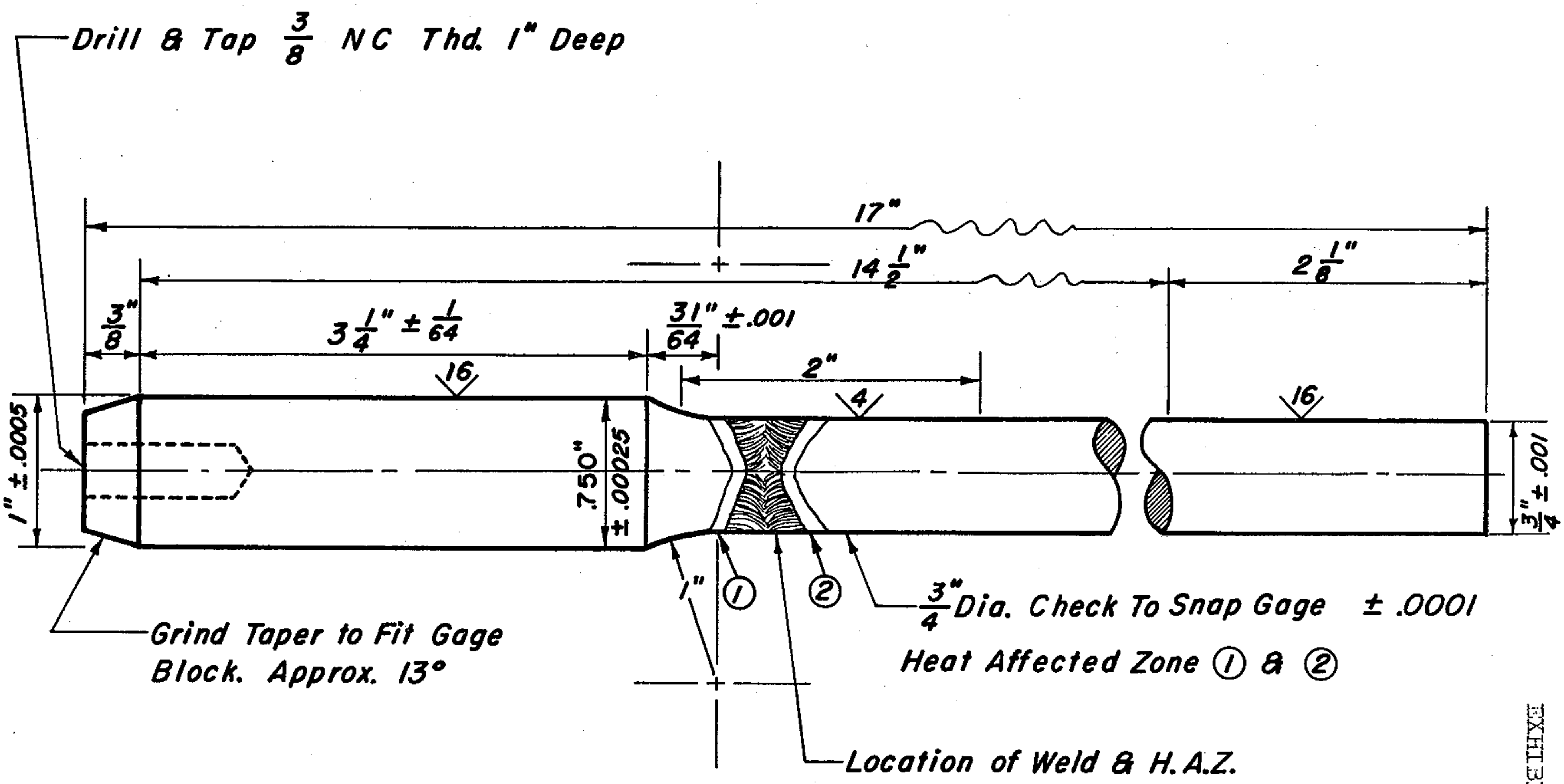
Exhibit 123



Macro sections through welded plates illustrating the position of the weld in the fatigue specimens.



Finished fatigue specimen. This one has been subjected to 10^7 stress cycles without failure. During a later retest it was stressed above its endurance limit and failed.



FATIGUE SPECIMEN

FATIGUE DATA AND SN DIAGRAMS

Points on the horizontal portions of the SN diagrams were not considered in calculating the solutions to the data. Points were eliminated where deviation from the SN curve exceeded the probable error by an amount greater than that specified under Chauvenet's criterion for discarding experimental values or where the inclusion of a single point made interpretation of the data impracticable.

The ordinates of the horizontal portions of the SN diagrams corresponding to the endurance limits were estimated from the data by visual inspection. These estimates were based on the ordinates of the "runout" points derived from specimens tested without failure, the ordinates of the lowest points derived from failed specimens (specimens with the lowest fatigue strength), the fit of these points into the limits of the probable error as extrapolated from the sloping to the horizontal portion of the SN diagram, and the abcissa of the break or knee in the diagram.

The fatigue specimens which failed through the gripped section were considered to have run without failure. These results are recorded on the SN diagrams as runout points (indicated on the diagrams as points with arrow attached) with abcissae smaller than 10^7 cycles.

EXHIBIT NO. 125

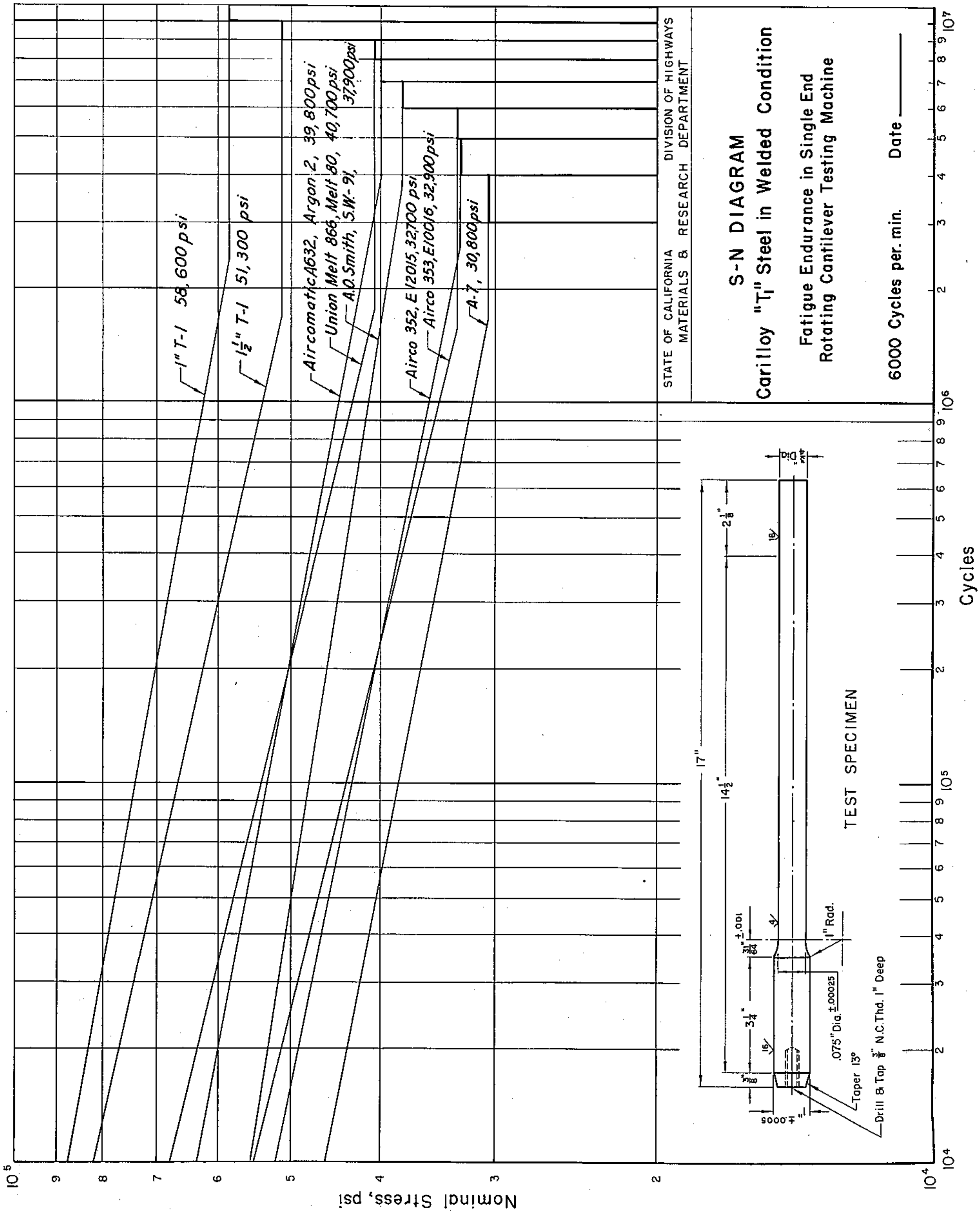
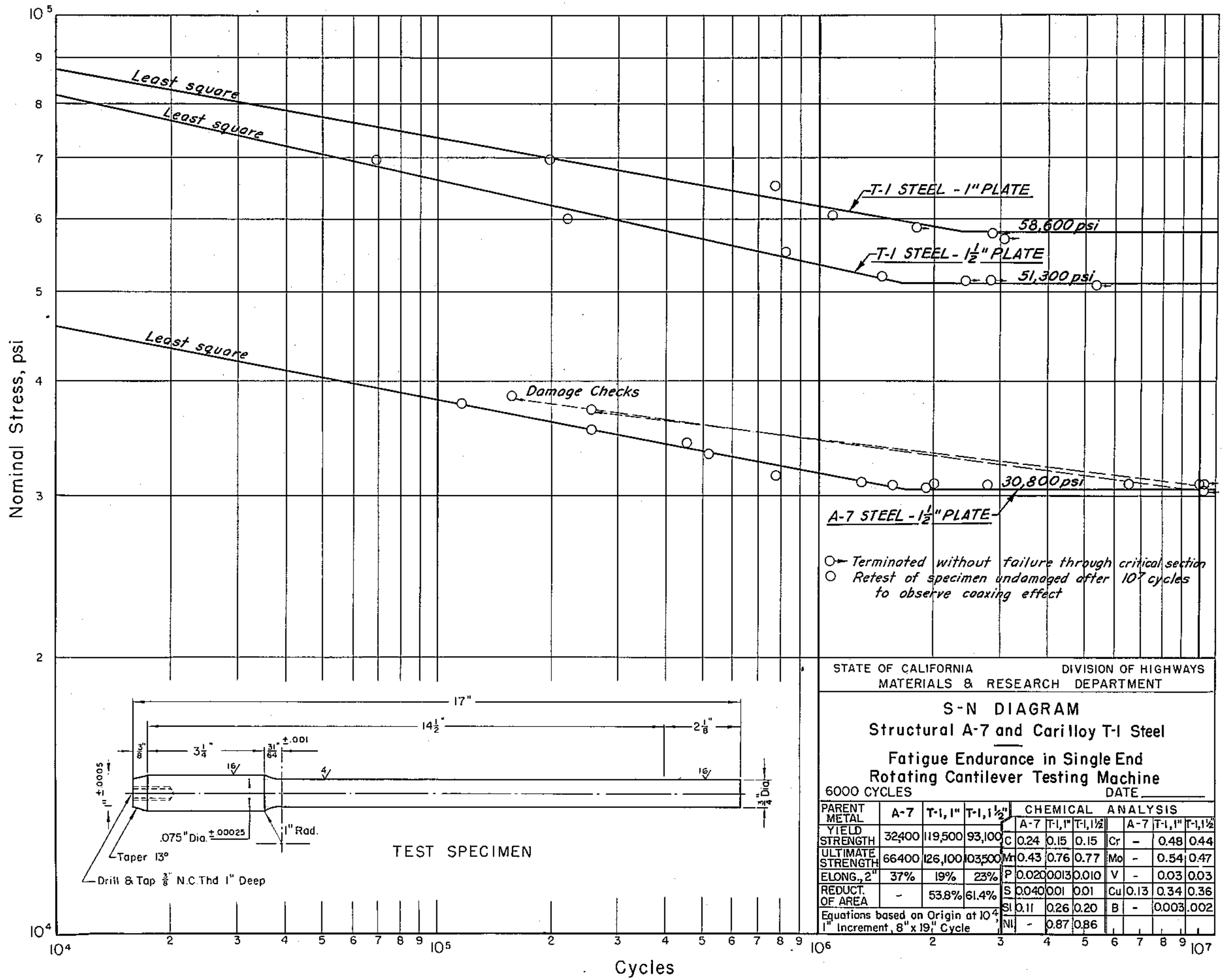


EXHIBIT NO. 126



STATE OF CALIFORNIA — DIVISION OF HIGHWAYS
MATERIALS & RESEARCH DEPARTMENT

S-N DIAGRAM
Structural A-7 and Carilloy T-1 Steel

Fatigue Endurance in Single End
Rotating Cantilever Testing Machine

6000 CYCLES — DATE ______

PARENT METAL	A-7	T-1, 1"	T-1, 1½"
YIELD STRENGTH	32400	119,500	93,100
ULTIMATE STRENGTH	66400	126,100	103,500
ELONG., 2"	37%	19%	23%
REDUCT. OF AREA	-	53.8%	61.4%

Equations based on Origin at 10^4, 1" Increment, 8" x 19" Cycle

CHEMICAL ANALYSIS

	A-7	T-1, 1"	T-1, 1½"		A-7	T-1, 1"	T-1, 1½"
C	0.24	0.15	0.15	Cr	-	0.48	0.44
Mn	0.43	0.76	0.77	Mo	-	0.54	0.47
P	0.020	0.013	0.010	V	-	0.03	0.03
S	0.040	0.01	0.01	Cu	0.13	0.34	0.36
Si	0.11	0.26	0.20	B	-	0.003	.002
Ni	-	0.87	0.86				

MANUAL WELDING

FATIGUE FAILURE PHOTOGRAPHS

AND

SN DIAGRAMS

OF

TRANSVERSE BUTT WELDS

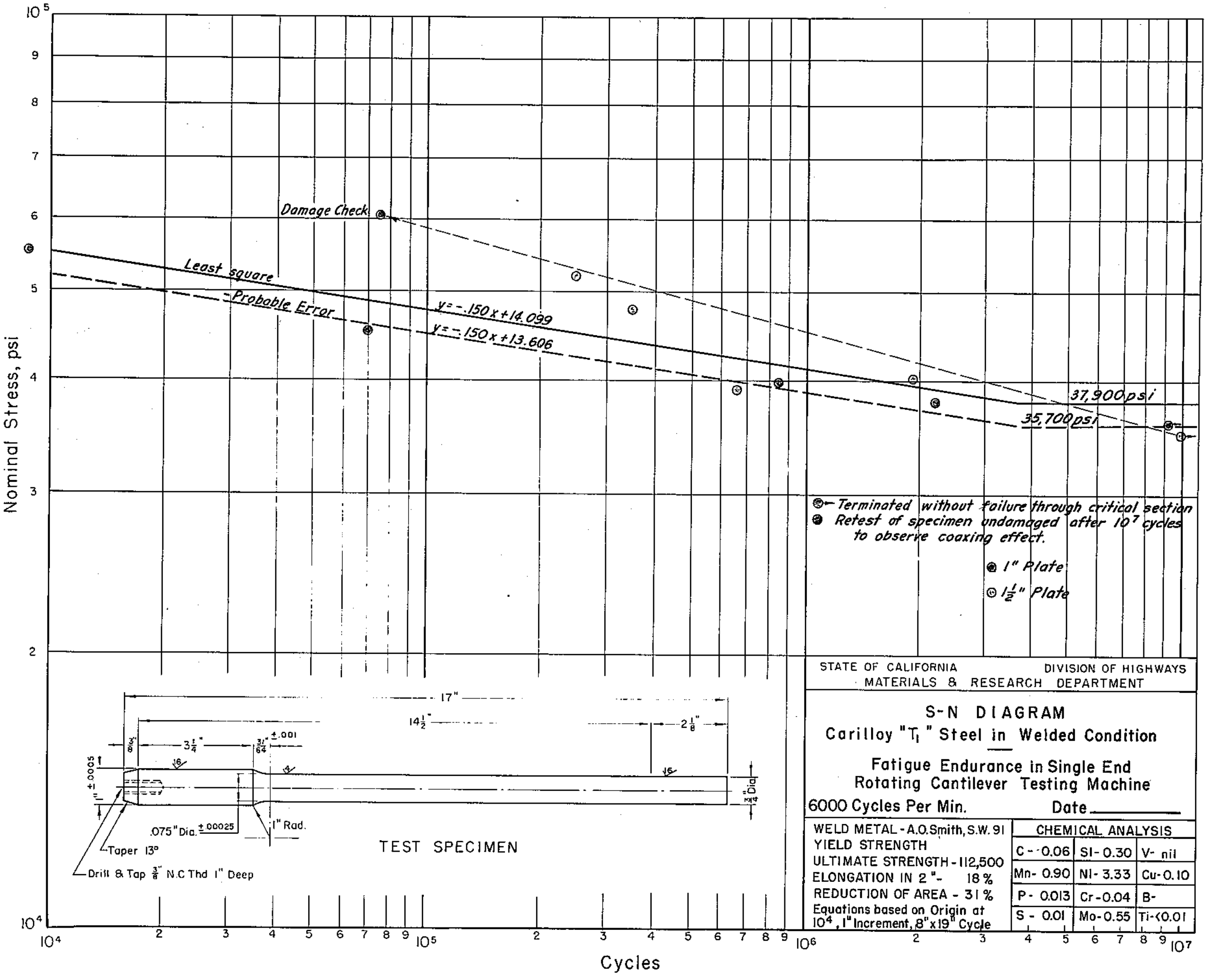
MADE WITH

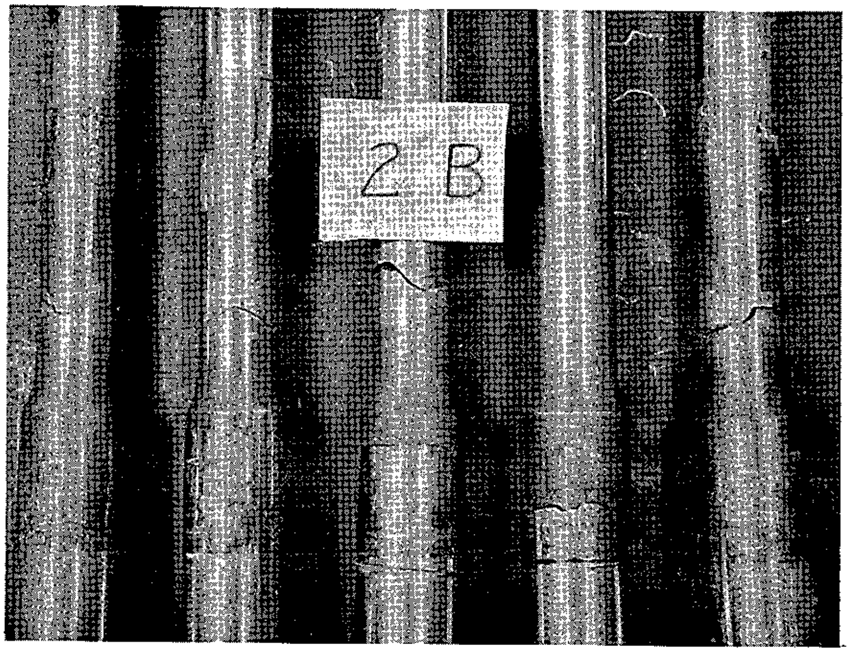
A.O.SMITH

S.W. 91, LOW HYDROGEN ELECTRODES

(E-11016 TENTATIVE)

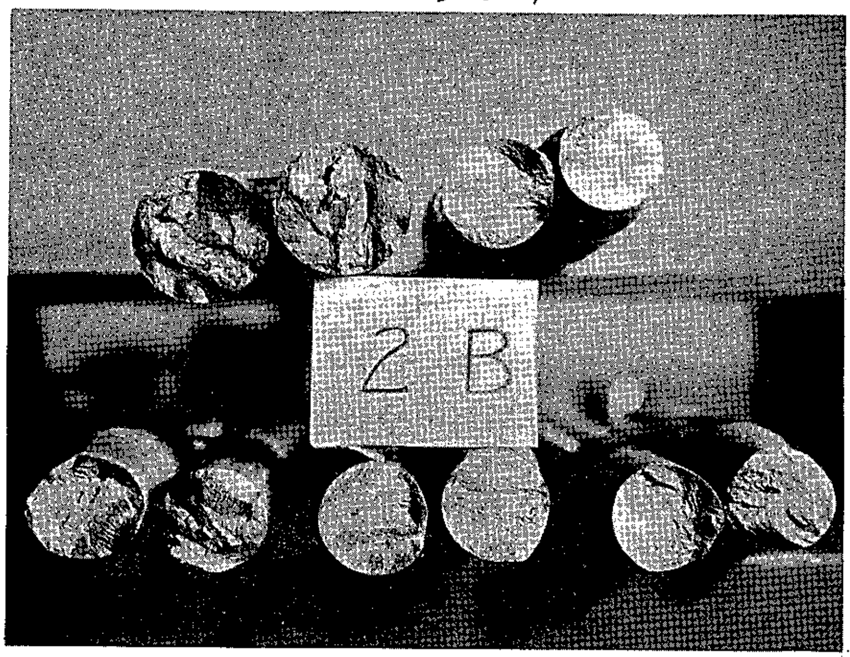
EXHIBIT NO. 127



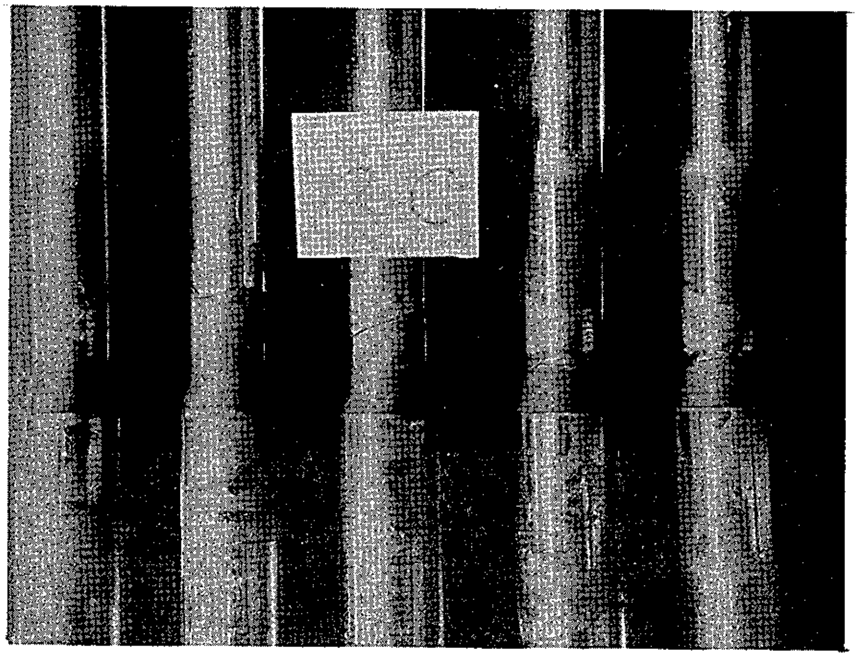


Side and end views of fatigue specimens prepared from a 1 inch butt joint manually welded using A.O.Smith SW91 low hydrogen electrodes. Failures started in the weld metal and the parent metal and propagated through the weld metal, heat affected zone, and the parent metal.

Endurance Limit	37,900 psi
Endurance Ratio	31.2 %

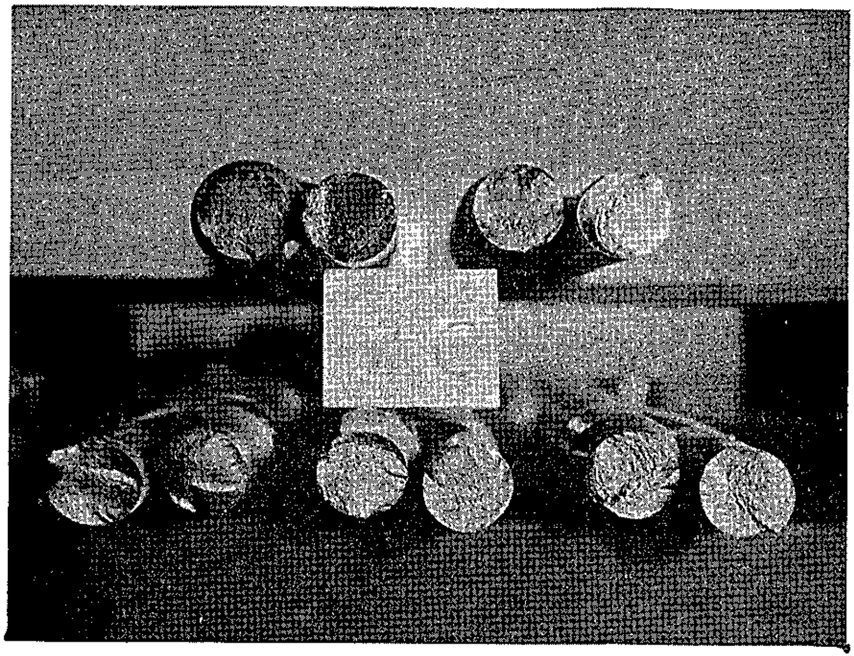


The specimen of the extreme left in both pictures contained numerous gas pockets and a separation extending over 1/4 the cross-section. Note also the break in the grip.



Side and end views of fatigue specimens prepared from a 1 1/2" butt joint manually welded using A.O.Smith SW91 low hydrogen electrodes. Failures started in the weld metal and the heat affected zone and propagated through the heat affected zone.

Endurance Limit	37,900 psi
Endurance Ratio	40.4%



MANUAL WELDING

FATIGUE FAILURE PHOTOGRAPHS

AND

SN DIAGRAMS

OF

TRANSVERSE BUTT WELDS

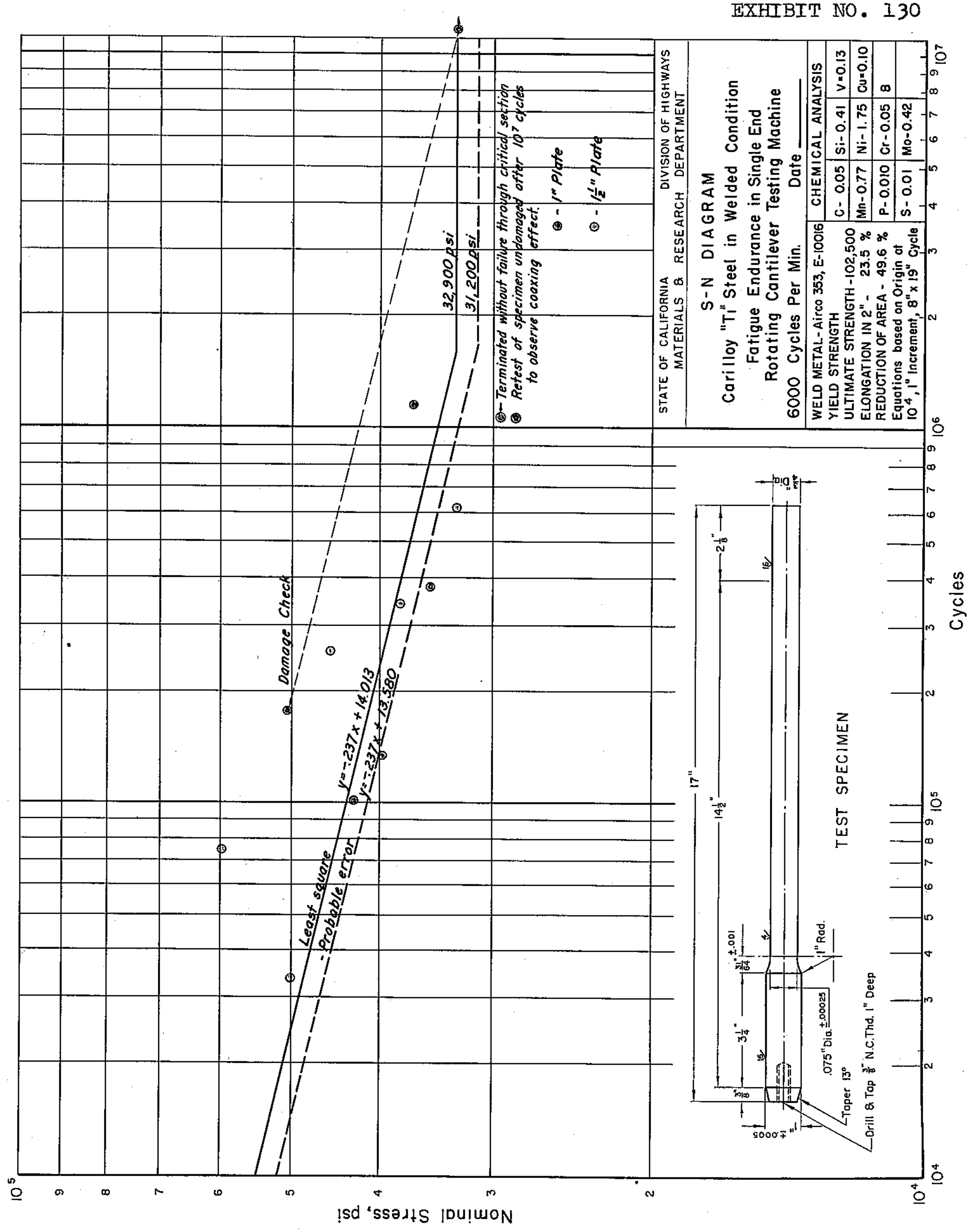
MADE WITH

AIRCO

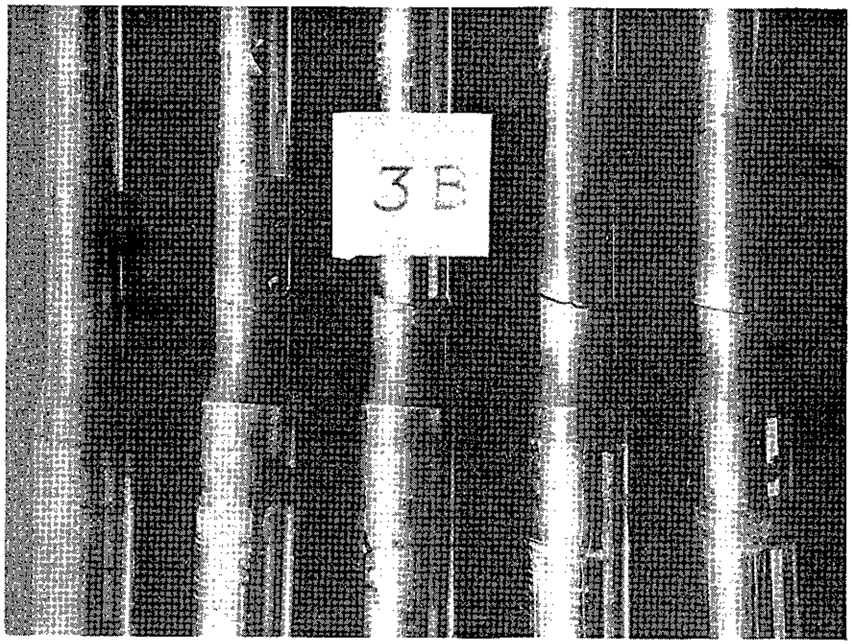
353, LOW HYDROGEN ELECTRODES

(E-10016)

EXHIBIT NO. 130

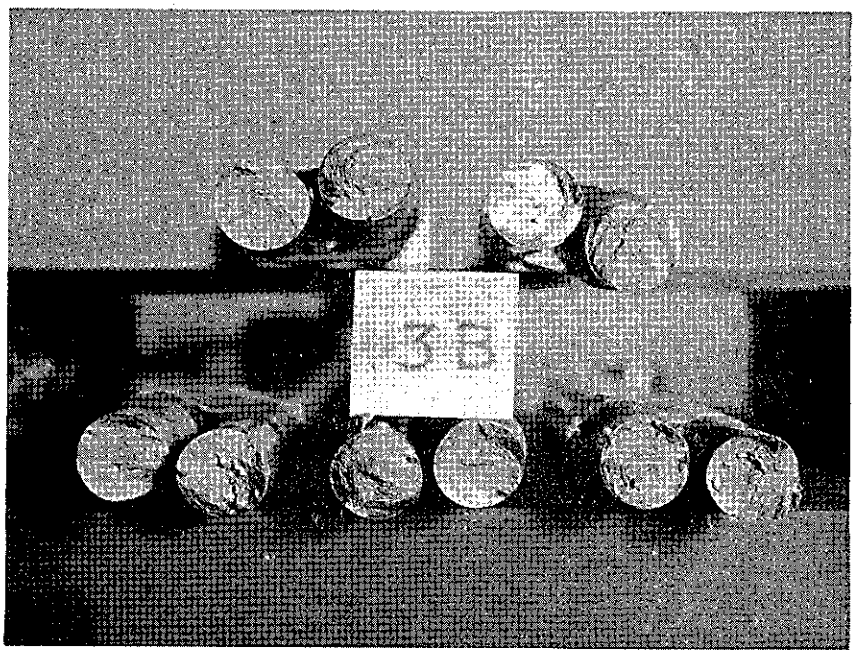


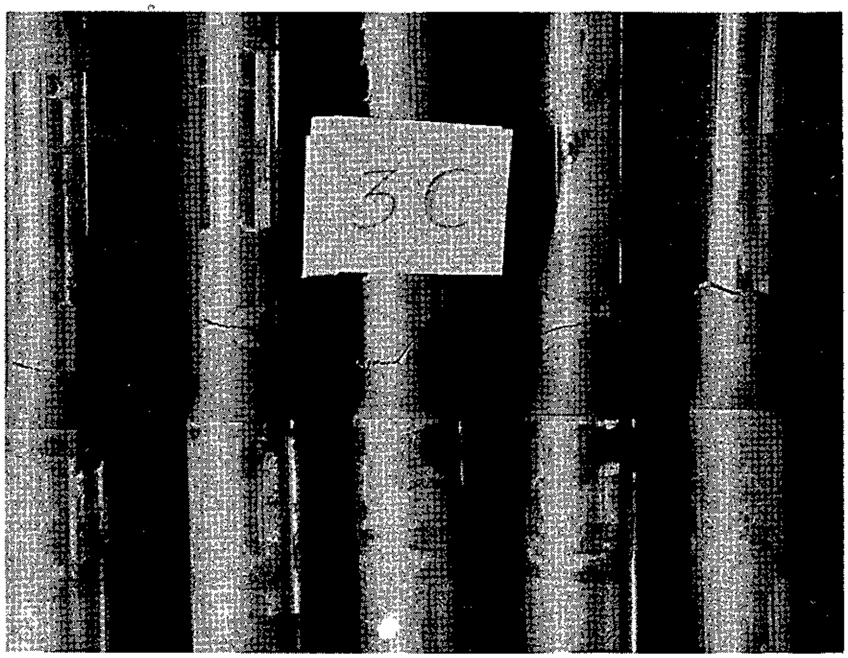
[illegible]



Side and end views of fatigue specimens prepared from a 1" butt joint manually welded using Airco 353 low hydrogen electrodes. Failures started in the weld metal and propagated through the heat affected zone.

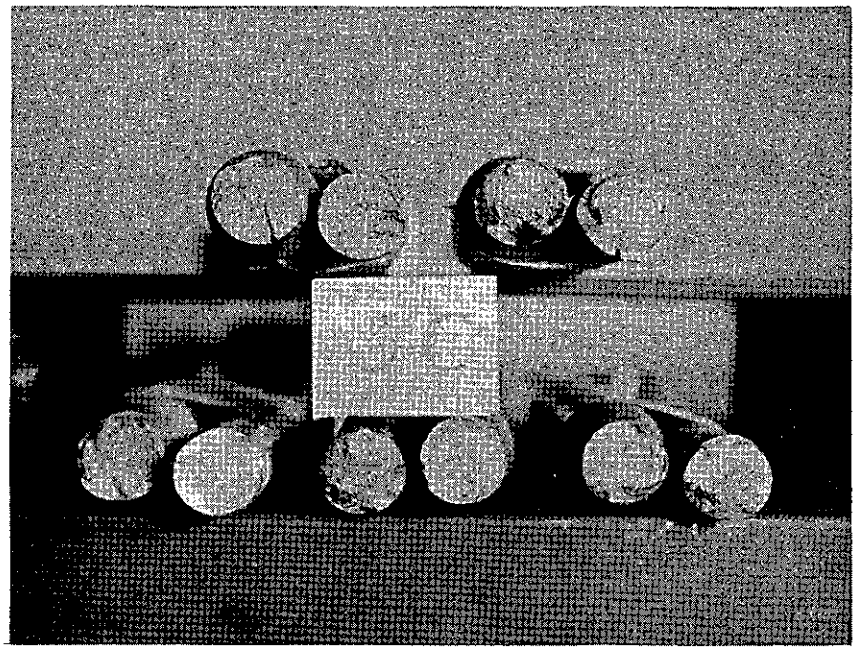
Endurance Limit	32,900 psi
Endurance Ratio	21.8 %





Side and end views of fatigue specimens prepared from a 1 1/2" butt joint manually welded using Airco 353 low hydrogen electrodes. Failures started in the weld metal and propagated through the weld metal and the heat affected zone.

Endurance Limit	32,900 psi
Endurance Ratio	34.3 %



AUTOMATIC WELDING

FATIGUE FAILURE PHOTOGRAPHS

AND

SN DIAGRAMS

OF

TRANSVERSE BUTT WELDS

MADE WITH

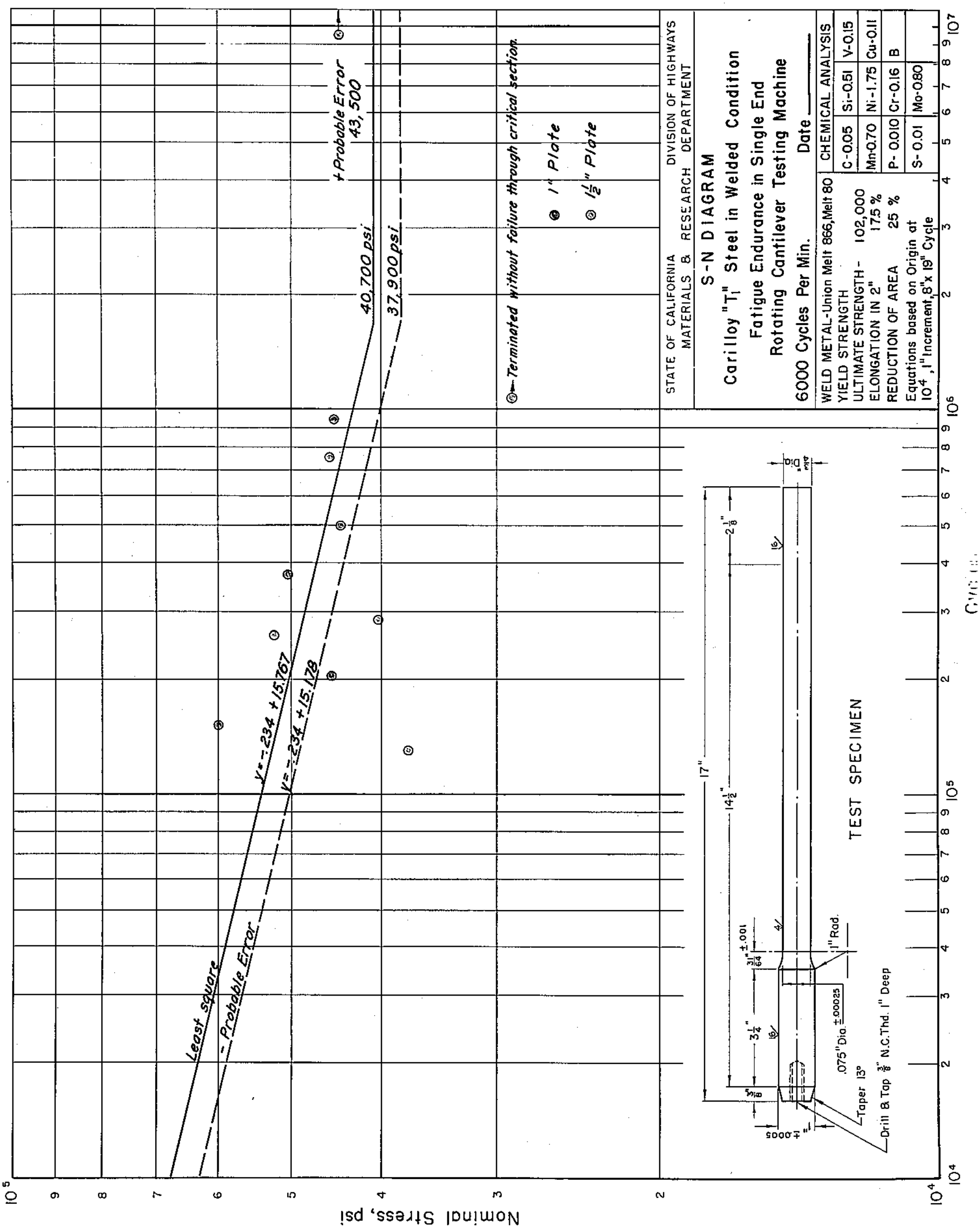
UNIONMELT SUBMERGED ARC PROCESS

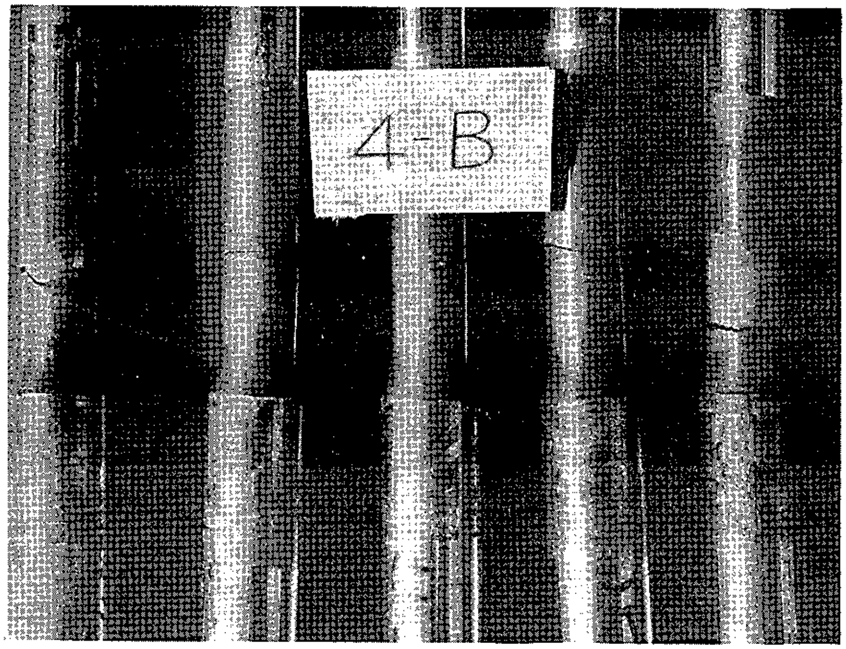
WITH

OXWELD 866 ELECTRODE WIRE AND #80 FLUX

[illegible]

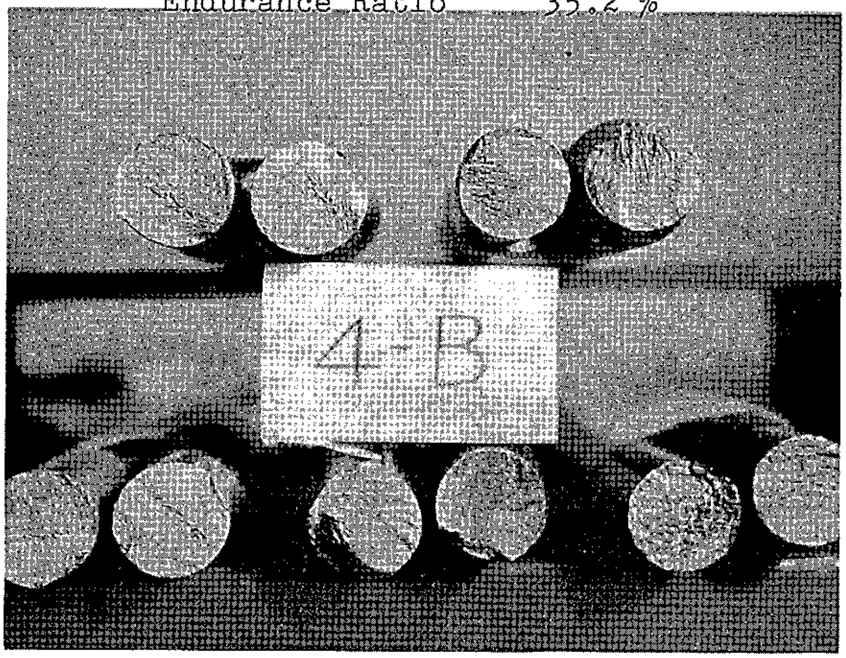
EXHIBIT NO. 133

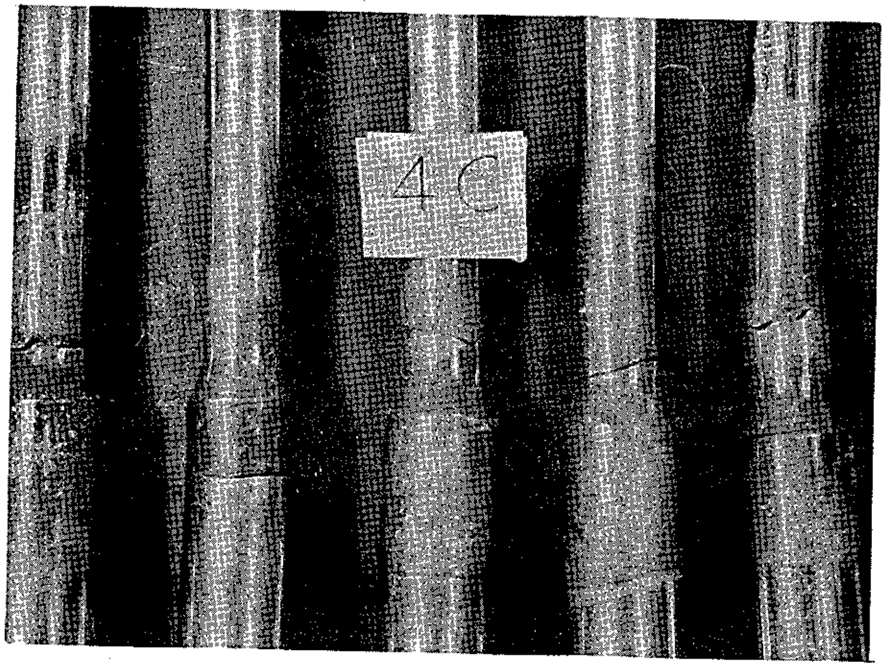




Side and end views of fatigue specimens prepared from a 1" butt joint welded with the Unionmelt submerged arc process using oxweld #866 electrode wire. Failures started in weld metal and heat affected zone and propagated through weld metal heat affected zone, and parent metal.

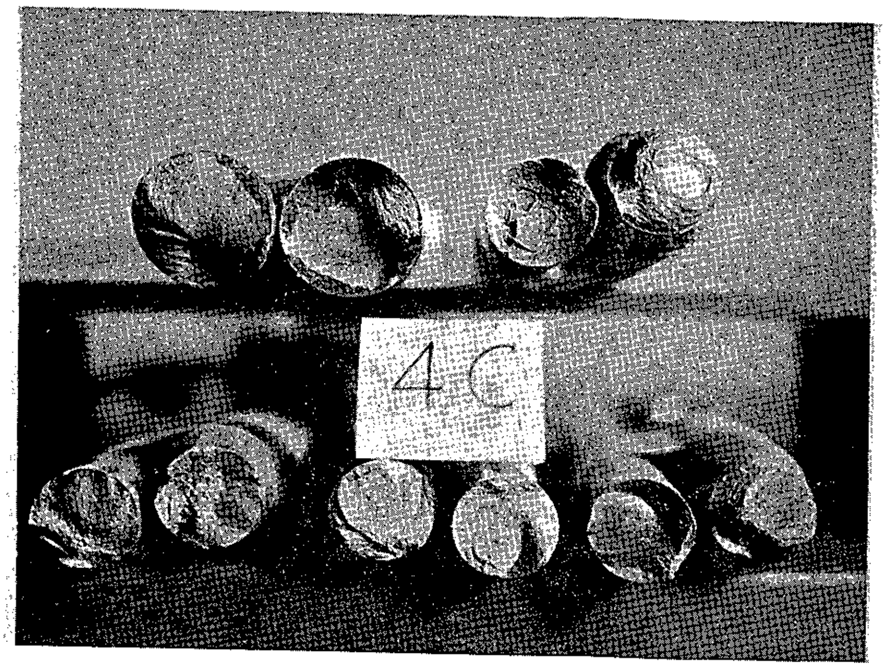
Endurance Limit 40,700 psi
Endurance Ratio 35.2 %





Side and end views of fatigue specimens prepared from a 1 1/2" butt joint welded with the Unionmelt Submerged Arc process using oxweld #866 electrode wire. Failures started and propagated through weld metal, heat affected zone, and parent metal.

Endurance Limit 40,700 psi
Endurance Ratio 44.9 %



Note specimen failing in grip of upper left and large slag inclusion in specimen at upper right. Bottom row specimens contained gas pockets.

SEMI-AUTOMATIC WELDING

FATIGUE FAILURE PHOTOGRAPHS

AND

SN DIAGRAMS

OF

TRANSVERSE BUTT WELDS

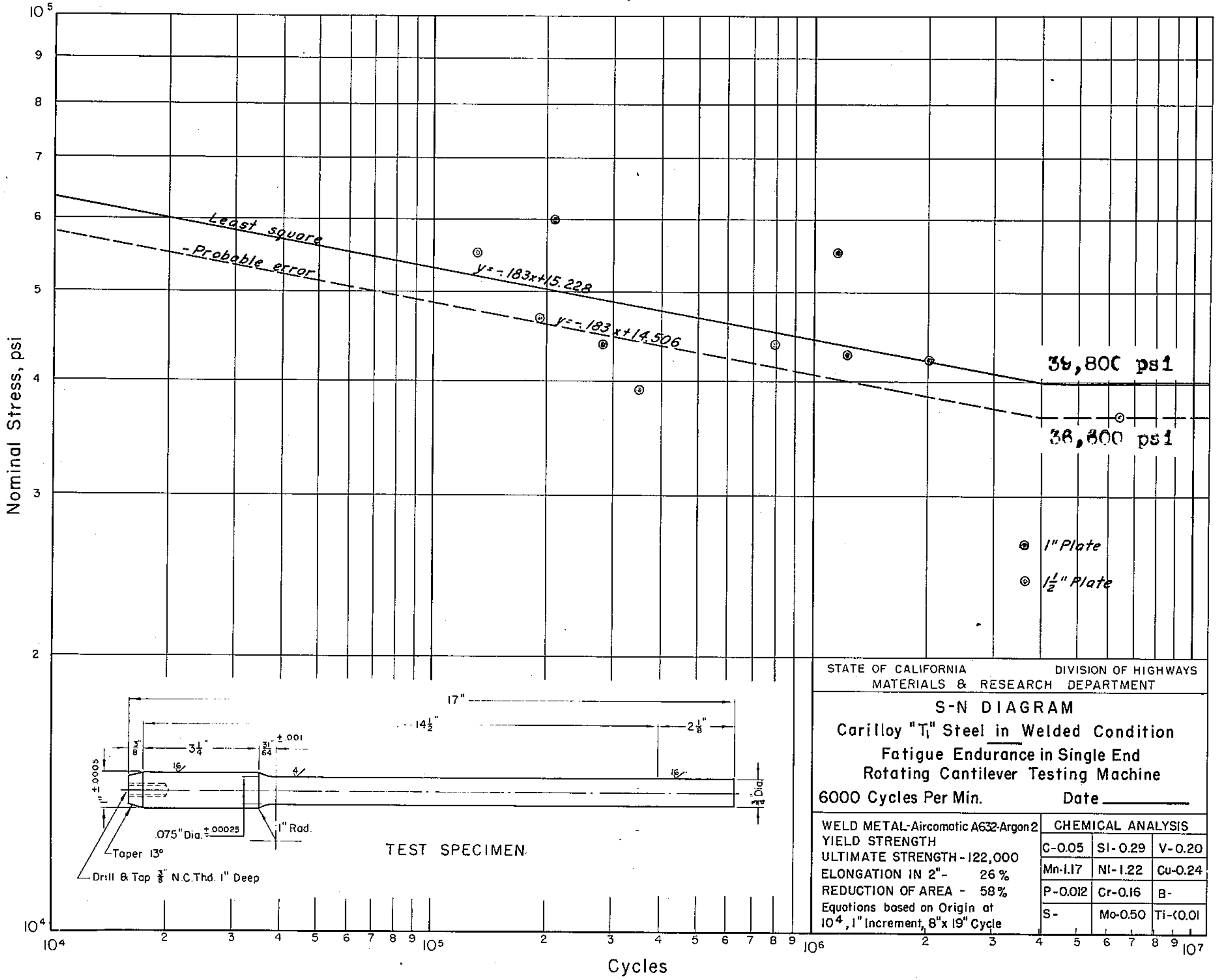
MADE WITH

AIRCOMATIC INERT GAS SHIELDED ARC PROCESS

WITH

A632 ELECTRODE WIRE AND A 98%A-2%O_2 GAS SHIELD

EXHIBIT NO. 136



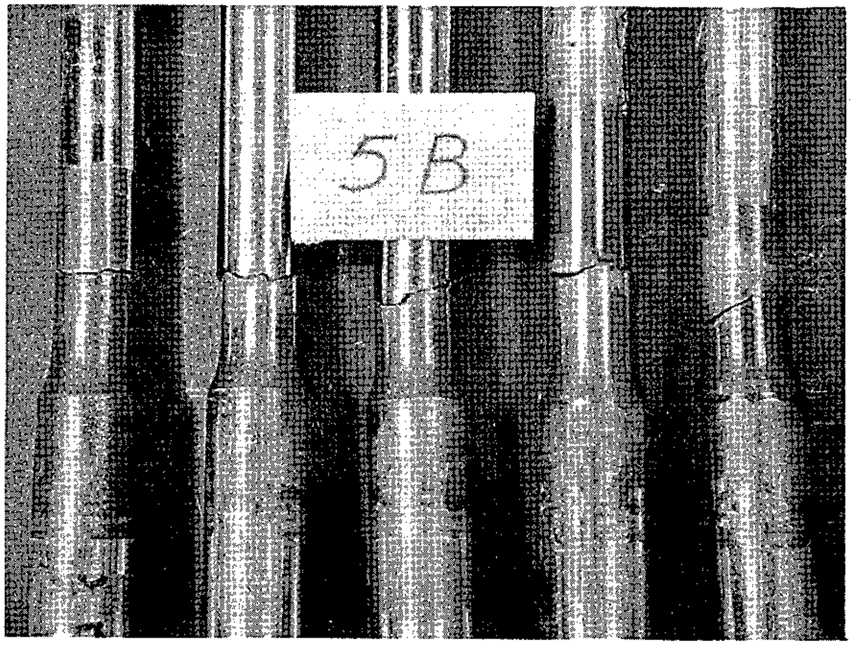
STATE OF CALIFORNIA — DIVISION OF HIGHWAYS
MATERIALS & RESEARCH DEPARTMENT

S-N DIAGRAM

Carilloy "T_1" Steel in Welded Condition
Fatigue Endurance in Single End
Rotating Cantilever Testing Machine
6000 Cycles Per Min. Date ________

WELD METAL - Aircomatic A632-Argon 2
YIELD STRENGTH
ULTIMATE STRENGTH - 122,000
ELONGATION IN 2" - 26 %
REDUCTION OF AREA - 58 %
Equations based on Origin at 10^4, 1" Increment, 8" x 19" Cycle

CHEMICAL ANALYSIS		
C-0.05	Si-0.29	V-0.20
Mn-1.17	Ni-1.22	Cu-0.24
P-0.012	Cr-0.16	B-
S-	Mo-0.50	Ti-(0.01



Side and end views of fatigue specimens prepared from a 1" butt joint welded with the Aircomatic gas shielded arc using A632 electrode wire. Failures started in the weld metal and propagated through the heat affected zone.

Endurance Limit 39,800 psi
Endurance Ratio 32.5 %